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Observations on Sexual Behaviour in some Australian Platystomatidae (Diptera, Schizophora)

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Figures 1–3 Manuscript received 31st July, 1972

SYNOPSIS

Sexual behaviour is described in four species of platystomatid flies, viz. *Euprosopia subula*, *E. tenuicornis*, *E. anostigma*, and *Pogonortalis doclea*. The role of specific recognition marks is discussed, especially in relation to certain structural modifications.

INTRODUCTION

The comparative study of sexual behaviour in animals is important for providing information on the degree of isolation between populations and the action of natural selection on factors which affect the ability of individuals to select mates of their own species.

In the genus *Euprosopia* it has been found that many of the most useful taxonomic characters take the form of structural modifications which are restricted to one sex only. Assuming that these modifications have been evolved by natural selection acting through the phenotype on the genotype, it should be possible to ascribe a specific function or functions to each of them. Modifications possessed by one sex only are most likely to perform a role relating to sexual processes, except for certain modifications of the female, which may be connected with oviposition. Study of sexual behaviour in *Euprosopia* gives promise of providing information on the function of these taxonomic characters and their role as specific recognition marks.

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Detailed observations of courtship or mating have been made previously for very few platystomatid species. Piersol (1907) has made observations on *Rivellia boscii* Robineau-Desvoidy, and Michelmore (1928) describes copulation in *Platystoma seminationis* (Fabricius). In the former there appears to be no complex preliminary courtship and the wings of the male are vibrated during copulation (as they probably would be at other times). In both these species it seems that the male feeds the female by regurgitation while mounted. Mr. G. A. Holloway informs me that he has observed courtship and mating in *Lenophila dentipes* (Macquart) on the trunk of a smooth-barked *Eucalyptus*. He states: "I noticed several pairs before copulation facing each other for up to five minutes, but I was not able to get too close. They do not wave their wings before copulation". I have observed mating pairs of several other species of *Lenophila* on the leaves of *Xanthorrhoea* spp. Specific identifications are not yet possible for these. Mr. Holloway has observed mating of *Duomyia iris* McAlpine at Crystal Springs, Western Australia. The mounted pairs were noticed on the peduncles of inflorescences of *Xanthorrhoea* sp. I have seen numerous pairs of *Pterogenia* sp. (probably *P. pectoralis* Hendel) mating on a damp rotting log in rain forest at the West Claudie R., near Iron Range, Queensland, and a single pair on the trunk of a living tree nearby.

Diurnal mating activity is apparently normal for all the species mentioned above and also for the species of *Euprosopia* and *Pogonortalis* dealt with below. Several mating pairs of *Duomyia nigricosta* Malloch, *D. maculipennis* Hendel, *D. octoseta* McAlpine, *D. curta* McAlpine, *D. hypene* McAlpine, and *D. loxocerina* McAlpine have been taken at mercury vapour light or other light after dark under trees which were apparently inhabited by the flies. Though this clearly demonstrates nocturnal mating for these species, it is possible that sexual behaviour was initiated before dark. In general on the nights when these specimens were taken there was no moonlight.

SPECIES OBSERVED

Euprosopia subula McAlpine is very closely related to *E. macrotegularia* Malloch, the only other species of the *macrotegularia* species-group. *E. subula* ranges from the Canberra district, Australian Capital Territory, to the Pioneer River district within the tropical zone of Queensland. The known range of *E. macrotegularia* is from the Tully River to Coen, Queensland. Apparently, therefore, it is not sympatric with *E. subula*, but the intervening area between the Pioneer and Tully Rivers is not sufficiently investigated to preclude the possibility that one or both species occur within it. It is therefore possible that a small area of overlap or front of contact may exist between the two, or there may even be a short cline connecting them. There is, however, no sign of clinal variation in the distinguishing morphological characters within the known range of either species. Material of *E. subula* used in this study was obtained at the Port Hacking River, immediately to the south of the Royal National Park south of Sydney.

Euprosopia tenuicornis Macquart is one of the *tenuicornis* species-group. It is widely distributed in eastern New South Wales and Queensland as far north as Townsville. The material used in this study was collected at Centennial Park, Sydney.

Euprosopia anostigma McAlpine also belongs in the *tenuicornis* species-group and is most closely related to *E. armipes*. It lives together with *E. armipes* at Iluka in northern coastal New South Wales and Bribie Island, southern Queensland. Material for this study was obtained at Kurnell, Botany Bay, where the species inhabits the same tree-trunks as *E. tenuicornis*.

Pogonortalis doclea (Walker). Paramonov (1957) has given the distinguishing characters for Australian species of *Pogonortalis*. *P. doclea* is very widely distributed on the Australian mainland. The population of *Pogonortalis* on Lord Howe Island is regarded as a separate species, *P. howei*, because of very small but consistent morphological differences. The species *P. commoni* is also closely related, but is known from a single specimen from south-western Australia, where *P. doclea* also occurs. Specimens of *P. doclea* were observed in copula in my garden at Bronte, Sydney.

METHODS OF STUDY

Copulating pairs of all four species have been seen under natural conditions. Because of their extreme wariness it was not possible to observe details of mating behaviour of *Euprosopia* spp. in the field. When placed in glass or perspex containers on the laboratory window sill these flies appeared to behave more or less normally and could be closely observed though the glass prevented very close viewing from some directions.

For this reason oblong perspex containers (9 cm x 7 cm x 3 cm) were used in some instances where close observation under a hand lens was necessary. To prevent the flies from slipping off smooth glass or plastic surfaces, use was made of the fact that lepidopterous larvae usually leave a web of silk adhering to the substrate on which they move. The larvae of *Cephrenes augiades* (Felder) taken from ornamental palms proved the most satisfactory of the species tried. They readily spun a loose web of silk which enabled the flies to cling to the surface but did not seriously impair the transparency of the container. *Pogonortalis* is much more readily approached in the wild than is *Euprosopia* and could be closely examined with a hand lens while in copula.

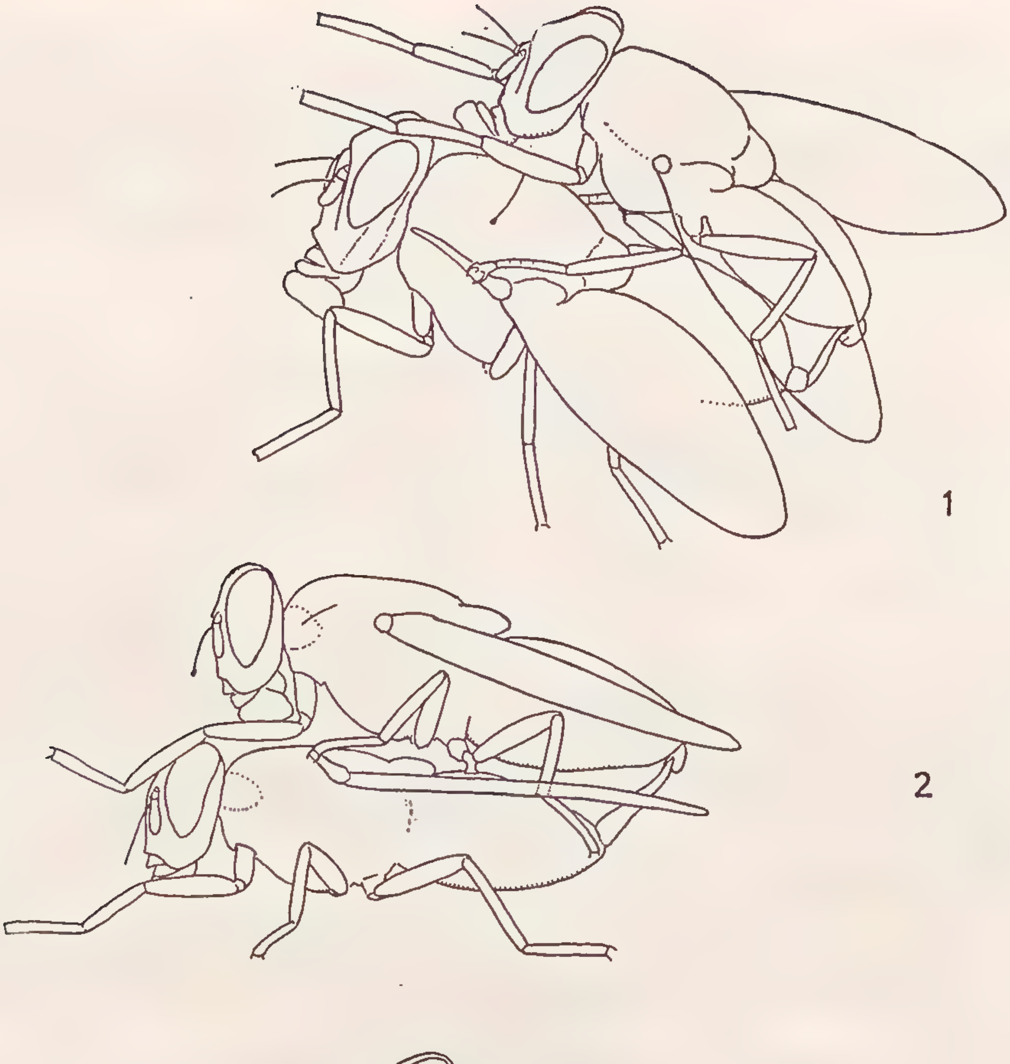
Specimens of *Euprosopia* could be kept alive in the laboratory for up to three weeks when fed daily on diluted black molasses. Individuals were isolated between periods of observation, when up to four individuals of each sex were placed together.

It would seem desirable to use unmated individuals, particularly females, for these investigations, but they may represent only a small proportion of those captured. Examination of long series of preserved females of *E. tenuicornis* suggests from the condition of the abdominal pubescence that *all* had been mounted. As the insects cannot yet be reared in the laboratory, use of virgin females was out of the question for this species, and improbable of attainment for others. Laboratory observations on *Euprosopia* spp. show that individuals of both sexes can mate a number of times, but in each experiment only a small proportion of the specimens used showed any tendency to mate.

DESCRIPTION OF BEHAVIOUR

Euprosopia subula

There is contact or intermittent contact between ♂ and ♀ for up to 30 minutes before mounting. The sexes approach each other and the ♂ displays its black fore tarsi to ♀. There is no wing flicking or evident displaying of wings. At times they both hold out the fore tarsi so that they make mutual contact. No regurgitative feeding nor tapping with ♂ proboscis on abdomen of ♀ was observed. The ♂ mounts ♀ from behind and immediately takes up the following position (fig. 1): the fore legs are extended anteriorly so that the tarsi pass above and in front of the eyes of the female, and are vibrated continuously; each middle tarsus grips the tegula of the



Figs. 1–3.—Pairs of *Euprosopia* spp. in copula. 1, *E. subula*. 2, *E. tenuicornis* (second position of mounting). 3, *E. anostigma* (second position of mounting).

female immediately in front of the basal swelling of the latter; the hind tarsi rest on the posterior part of the preabdomen of the female; the ovipositor of the female is extended upwards to pass beneath the hypopygium of the male so that coitus appears to be achieved. The vibrations of the fore legs of the ♂ result, for a considerable proportion of the time at least, in a hammering action of the spatulate bristle of the ♂ fore femur on the anterior part of the mesoscutum of ♀. After a short period the ♂ stops vibrating the fore tarsi and prepares to feed the female by regurgitation. This may happen to the left or to the right, with corresponding reversal of the members used; the process is here described for the action taking place towards the right. The ♂ places its right fore tarsus on the substrate leaning its head over to right of head of ♀. The left fore leg of the ♂ is crooked over the head of ♀, the ♂ tibia over the ♀ postfrons, and the ♂ tarsus over ♀ antenna. The ♀ raises the right fore tarsus to touch the right side of the extended ♂ proboscis with its ventral surface. In a short time the ♀ replaces its fore tarsus on the substrate and turns its head so that its proboscis contacts that of ♂. Mutual stroking of proboscides ensues until a globule of liquid appears on the ♂ proboscis which is immediately ingested by the ♀. The pair then return to their former position with the fore tarsi of ♂ vibrating over the eyes of ♀. The feeding process may take place two or three times during each mounting. The period of mounting varied from 7 to 11 minutes in the observed instances. The ♂ dismounts when the ♀ gives restless movements of the legs or body. One pair mounted three times in succession with only short intervals between. As these individuals were confined in a small space, it is uncertain if such repeated mounting would take place in the wild. Between matings the ♀ often offered ♂ a middle or fore tarsus and there was much contact of tarsi. After separating the third time the ♀ of this pair repeatedly approached ♂, touching the wings, abdomen, and legs of latter with its fore tarsi. When ♂ retreated, ♀ pursued persistently. The ♂ flew away twice but could not totally escape ♀ in the confined space.

Euprosopia tenuicornis

Preliminaries to mounting are minimal in this species. On encountering a ♀, the ♂ walks round behind it and may briefly tap on the wings or abdomen with the proboscis before attempting to mount.

There are two distinct positions when mounted and only during the second of these is coition achieved.

The first position taken up immediately on mounting proceeds as follows: the ♂ fore tarsi are placed on the ♀ notopleural region or the anterior part of the ♀ mesoscutum and may be flicked upwards, or they may tap on the ♀ mesoscutum, and subsequently they are extended forwards and vibrated over the eyes of ♀; the mid-tarsal claws of ♂ are hooked over the anterior extremity of ♀ tegulae, the latter being pulled upwards to point in an anterodorsal direction; the ♂ hind tarsi rest on the posterior part of the preabdomen of ♀; the ♂ proboscis is tapped on the ♀ mesoscutum in some cases and not in others; ♂ may regurgitate a drop of fluid on to the labella of proboscis and then deposit the drop on the thorax of ♀, subsequently ingesting it again, but this was not observed to happen in most cases; during most of first position stage ♂ hind trochanters are held clear of ♀ abdomen with occasional contact only; rapid jerking movements of the body of ♂ take place, usually for one or few seconds before the second position is assumed; these movements cause a backward brushing of the ♂ hind trochanteral processes on tergite 3 of the ♀ abdomen. The first position may be held for as long as 10 minutes before ♀ shakes off ♂ without achieving coition. On other occasions, presumably when ♀ is more tractable, the first position stage is passed through in a few seconds and the second is taken up.

The second position is taken up at the moment coition is achieved and is continued until coition is broken. It is more or less immobile. The knee joint of the ♂ fore leg is slightly crooked over the head of ♀ so that the ♂ tibia rests loosely on the upper part of eye of ♀, the tarsus, which projects anteriorly, being occasionally flicked upwards through a small angle from its articulation with tibia; the placement of the middle and hind tarsi remain as in the first position; the ♂ hind trochanteral processes rest on ♀ tergite 3 and appear to remain quite stationary. On one occasion only during the second position stage, ♂ was observed to tap on ♀ thorax with proboscis and then regurgitate a drop of fluid on to ♀. This was later ingested by the ♂, after which the pair separated by the ♀ taking flight.

The period for which a pair remain mounted is usually 9 or 10 minutes, but was in one case 35 minutes. Often, particularly if mounting is of longer duration, the first and second positions alternate, with the second occupying the greater part of the time. The return to first position always coincides with a break in the genital coupling.

Euprosopia anostigma

The ♂ approaches ♀ from behind, touches ♀ wings with fore tarsi and ♀ tergite 5 several times with proboscis. ♀ extends ovipositor and secretes a drop of fluid on to substrate, apparently from anus. This is ingested by ♂. ♂ then attempts to mount but is often unsuccessful.

As in *E. tenuicornis* there are two different mounted positions, with coition achieved on taking up the second position and continued for its duration.

The first position taken up on mounting is as follows: each ♂ fore tarsus is placed across notopleural region of ♀ with the claws over ♀ mesopleuron, and the tarsi are repeatedly flicked upwards and forwards across and above eyes of ♀; the claws of each ♂ middle tarsus are hooked across the anterior surface of the broadened basal part of the costal vein of the ♀ wing; the distal part of the ♂ hind tibia rests on the distolateral part of preabdomen; the ♂ proboscis taps continuously on anterior part of ♀ mesoscutum; the slight jerking of the whole body of ♂ appears to cause contact between ♂ hind trochanters and ♀ abdominal tergite 3, every time the fore tarsi are flicked over ♀ eyes, but no definite stroking movements have been seen.

In the second position there is more movement than in *E. tenuicornis*; the ♂ fore tibiae are placed across the upper part of ♀ eye so that the ♀ head is held apparently quite firmly by the depressed ventral areas of the ♂ tibiae, the tarsi projecting forwards; the ♂ middle tarsi continue to cling to the extreme base of the ♀ costae; in one case the ♂ third tarsi were hooked round the apex of ♀ preabdomen on either side of ovipositor sheath subparallel and touching on ventral surface, but in other cases the placement of the hind legs was not noted; the ♂ hind coxae and trochanters are held clear of the ♀ abdomen. The following movements occur: ♂ proboscis taps almost continuously on ♀ mesoscutum; the head of ♀ jerks from side to side for all or much of the time within the grip of the ♂ fore tibiae which possibly provide the impetus for the movements; at times there are rocking movements of the pair around a vertical axis as if both were transfixed by a pin passing through the centres of their thoraces.

In apparently successful attempts at copulation the pair remained mounted for periods of from a little over one minute to 10½ minutes.

Pogonortalis doclea

Mating of this species has been observed on a grass stem, a hibiscus leaf, and other objects close to the ground in a suburban garden. Courtship and initial stages of mating have not been observed. The male mounts much further back on the female than is the case in the species of *Euprosopia*, and clings to the abdomen of the latter with the body only slightly inclined forwards from the vertical. The fore tarsi of ♂ are placed close together on tergite 2 of ♀; the middle tarsi have their knees bent up towards the wing bases with their tarsi apparently hooked on to lateral margins of tergite 2 or 3 of the female; the hind legs are bent downwards and flexed at the knees under the ♀ preabdomen immediately behind segment 5 of the latter. The wings of the ♂ remain flexed back over the abdomen. The ♂ remains immobile on the ♀ except for slight movements of the proboscis. The ♀ holds the wings more or less extended laterally and occasionally vibrates them in a horizontal plane, at the same time moving the proboscis up and down. Sometimes the ♀ walks round a little. They have been observed mounted for up to 4 minutes but it is not known how long they were mounted before observation commenced. There is probably no regurgitative feeding in the mounted position.

DISCUSSION OF RECOGNITION MARKS

The observations on mating behaviour of *Euprosopia* species provide evidence of several kinds of specific recognition marks. These include morphological and behavioural elements, but these elements often combine into a complex recognition mechanism. It would therefore serve no purpose to classify the mechanisms into strictly morphological and behavioural categories. What little has been observed in *Pogonortalis* suggests that there may be a less complex system of recognition marks in this genus. This may be due to the fact that there is apparently only a single species in most districts where this genus occurs in Australia, whereas there are often numerous species of *Euprosopia* in a single district, e.g. there are eight species in coastal areas near Sydney and about fourteen species on the Atherton Tableland.

In *Euprosopia* there are often specific differences in wing pattern but the differences between closely related species are usually small. It is doubtful if the vision of these insects is adequate for distinguishing such small differences of wing pattern as exist between *E. tenuicornis* and *E. anostigma*. As these species do not appear to display the wings before courtship, there is no evidence for recognition marks in the wing patterns of these species.

There are differences in facial markings among the species of *Euprosopia*. These tend to be fairly constant within a species group, but often differ between species groups. Individuals of *E. subula* face each other before mating so it is conceivable that they could see and recognize the facial markings. In *E. tenuicornis* and *E. anostigma* the pair do not face one another, although the facial markings are well developed in these species.

The entirely dark-coloured fore tarsi of *E. subula* contrast with those of other sympatric *Euprosopia* species (except the geographically restricted *E. remota*) which have the basal segment of the tarsus predominantly pale-coloured. The fore tarsi of *E. subula* are displayed by both sexes before mating, and in all three species of *Euprosopia* observed the ♂ places the fore tarsi near the eyes of the female for at least part of the time after mounting. It is therefore possible that the colour of the fore tarsus is used as a recognition mark by at least some species of *Euprosopia*.

In both *E. subula* and *E. macrotegularia* there is a long fine spatulate ventral bristle on the ventral surface of the fore femur in ♂. As the above observations on *E. subula* show, these bristles tap on the thorax of the ♀ while the ♂ is mounted and is vibrating its black fore tarsi over the eyes of the ♀. This would enable both visual and tactile recognition of the ♂ by the ♀ to take place simultaneously.

In the ♂ of *E. anostigma* the fore tibia has a ventral to anteroventral longitudinal area of cuticle which is in part thrown into undulating folds and is covered with very minute, socket-based vestiture, while near the base of the tibia there is a ventral group of stout, dense black setulae. In the ♀ the area of modified cuticle is little developed and the group of black setulae is absent. As noted above, the fore tibiae of the ♂ are used during mating to grip the head of the ♀. The modifications of the tibia are undoubtedly an adaptation to enable the ♂ to obtain a firm grip. By contrast, in the ♂ of *E. tenuicornis* the fore tibiae are little modified and rest loosely on the head of the mounted ♀. Thus in these two species both the structure and manner of use of the ♂ fore tibiae could aid specific recognition of the ♂ by the ♀.

The placing of the ♂ fore tarsi across the notopleural region of ♀ in the early stages of mounting and subsequent flicking of the tarsi from this position are features of the initial stages of mounting in *E. anostigma.* This is the only one of the three *Euprosopia* species studied which has a pair of curved somewhat spatulate bristles arising from the posterior side of the distal extremity of the fore basitarsus of ♂ (also present in *E. armipes* and *E. monodon* of the same species group). It is possible that these specialised bristles impart a tactile stimulus to the ♀ during flicking which aids recognition, although the precise nature of the contact has not been ascertained.

In *E. tenuicornis* and *E. anostigma* (as in other species of the *tenuicornis* species-group) the humeral bristle is absent in the ♀, but present in the ♂. This specialised condition of the ♀ appears to be an adaptation enabling the ♂ to place its fore tarsi more firmly on the humeral-notopleural region. It is noteworthy that in the ♀ of *E. tenuicornis* the hairs on the posterior part of the humeral callus are much shortened by comparison with its ♂, or with the ♀ of *E. anostigma.* This may provide a recognition mark for the ♂. In the three available ♀♀ of *E. monodon*, which is very closely related to *E. tenuicornis*, the hairs are absent from all but the anterior extremity of the humeral callus, and its surface has a polished appearance. This condition suggests that in this species the ♂ rubs the humeral callus of the ♀ while mounted till the pruinescence has been removed from the latter.

The gripping of the ♀ with the mid-tarsal claws of the ♂ in platystomatid flies may be an essential element in maintaining the mounted position and enabling coition to proceed. In each of the four platystomatid species observed a different part of the female is gripped. In *Pogonortalis doclea* it is the lateral margins of the abdomen, whereas in the observed *Euprosopia* spp. it is always thoracic structures that are held.

The differences in the structure of the ♀ tegula in *Euprosopia* spp. are clearly adaptations to the specific mode of gripping by the ♂. In *E. subula* the very long, sub-cylindrical tegulae of the ♀ are held round the middle by the mid-tarsal claws of the ♂. In *E. tenuicornis* the tegulae of the ♀ are too short to be held in the above fashion and the ♂ tarsal claws pass over the apex of the anterior projection. In *E. anostigma* the middle tarsus of the male does not touch the ♀ tegula, but instead its claws are hooked on to the costal region of the ♀ wing. In this species the ♀ tegula is almost unmodified, being similar to that of the ♂. There are numerous species of *Euprosopia* with the tegula variously modified in the ♀, all having it practically unmodified in the ♂ (e.g. *E. macrotegularia, tegularia, remota, crassa, biarmata, conjuncta*). It would be interesting to compare the way in which the ♀ tegula is utilised by the ♂

in these species. If, in these insects, the ♂ is able to recognize the ♀ of its own species by the kind of supporting structure provided for its middle tarsi, then the ♀ is probably also able to recognize its own male by the position in which it attempts to place the middle tarsi.

The remarkable hind trochanteral processes of the ♂ of *E. tenuicornis* are used to brush or comb the soft downy pubescence on tergite 3 of the ♀ abdomen. No other species of the *tenuicornis* species group possesses specialised hind trochanteral armature in the ♂, or specialised pubescence on tergite 3 of the ♀. Hence these structures almost certainly provide mutual recognition marks for the sexes of this species. All of the very numerous preserved ♀ specimens of *E. tenuicornis* show evidence of this combing action by the male, suggesting that virgin females are rarely captured. The appearance of the combed pubescence on these specimens suggests that some liquid secretion contacts it during the combing process. So clear is the evidence of combing on the preserved ♀ specimens that it was possible to infer the manner of action of the ♂ trochanteral processes before observations on living specimens were made.

In *E. separata* and *E. comes*, closely related species of the *separata* species group, there is a hind trochanteral brush of dense setulae in the ♂, which is not situated on such a well developed process as in *E. tenuicornis*. Examination of the ♀ abdomen suggests that the brushes have been applied to tergite 4 in both species. In *E. separata* there is generally a shining spot on each side of tergite 4 of ♀ where the pruinescence has been completely rubbed off, probably from vigorous rubbing by the brushes on the male trochanters. In *E. comes*, in which the brushes are not mounted on tubercles, the rubbing appears to be much gentler, for though there are generally two disturbed spots on tergite 4, usually very little of the pruinescence has been removed. It appears that the method of rubbing by the male may provide a recognition mark for the females in these partly sympatric species. *E. ventralis* (*ventralis* species-group) shows a smooth rubbed area on each side of tergite 5 of ♀. In this species the tergite is possibly rubbed with some part of the ♂ hind legs, though the latter are not noticeably modified for the purpose.

The process of regurgitative feeding of the ♀ by the ♂ while mounted in *E. subula* would appear to offer possibilities for recognition marks both from the chemical and purely physical aspects. In *Rivellia boscii* and *Platystoma seminationis* (see Piersol, 1907, and Michelmore, 1928) there is also regurgitative feeding while mounted. The anal feeding of the ♂ by the ♀ in *E. anostigma* is also a habit which could involve chemical as well as physical recognition marks.

CONCLUSIONS

The observations here recorded for three species of *Euprosopia* indicate that numerous elements of the sexual behaviour pattern probably contribute to mutual specific recognition in the mating pair, both before and during mating. Recognition marks include specific morphological adaptations and specific methods of employing these. Because there are numerous comparable secondary sexual modifications in other species of *Euprosopia* (as in many other insect groups), it seems probable that many of these also serve as recognition marks or aid the functioning of ethological recognition marks.

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Table 1. Comparison of mating behaviour in *Euprosopia* species

	subula	*tenuicornis*	*anostigma*
BEFORE MOUNTING	♂ displays black fore tarsi, ♀ does so to a smaller extent.	No display of fore tarsi.	No display of fore tarsi.
	No tapping of ♂ proboscis on ♀ wings or abdomen.	♂ taps with proboscis on ♀ wings or abdomen (sometimes).	♂ touches ♀ wings with fore tarsi and taps on ♀ tergite 5 with proboscis.
	No anal feeding.	No anal feeding.	♀ produces fluid from anus which is ingested by ♂.
MOUNTED STAGE 1 (no coition)	(Stage absent).	Initially ♂ places fore tarsi on ♀ notopleural area or anterior part of mesoscutum, then may flick fore tarsi upwards or tap them on ♀ mesoscutum. Subsequently ♂ extends fore tarsi forward and vibrates them over eyes of ♀.	♂ places fore tarsi on notopleural region of ♀ and repeatedly flicks them forward over eye.
		♂ mid-tarsal claws grip apices of ♀ tegulae.	♂ mid-tarsal claws grip costa of ♀ wing.
		♂ combs pubescence of ♀ abdomen with hind trochanters.	♂ does not comb ♀ abdomen but ♂ trochanters may contact ♀ abdomen.
		♂ does not tap ♀ thorax with proboscis.	♂ taps ♀ thorax with proboscis.
MOUNTED STAGE 2 (coition achieved)	♂ extends fore legs over ♀ head and vibrates them continuously, thus tapping ♀ thorax with spatulate bristle of femur.	♂ passively rests fore leg on head of ♀.	♂ grips head of ♀ firmly between fore tibiae and jerks it from side to side.
	♂ mid-tarsal claws grip ♀ tegula beyond base.	♂ mid-tarsal claws grip apex of ♀ tegula.	♂ mid-tarsal claws grip costa of ♀ wing.
	♂ feeds ♀ by regurgitation.	No regurgitative feeding.	No regurgitative feeding.
	♂ does not tap thorax of ♀ with proboscis.	♂ seldom taps ♀ thorax with proboscis.	♂ taps ♀ thorax with proboscis for much of time.

THE GARFISHES (HEMIRAMPHIDAE) OF AUSTRALIA AND NEW ZEALAND

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Figures 1–23

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SUMMARY

Twenty species and subspecies of garfishes are recognized from Australian and New Zealand waters: *Arrhamphus s. sclerolepis*, *A. s. krefftii*, *Euleptorhamphus viridis*, *Hemiramphus far*, *He. robustus*, *Hyporhamphus r. regularis*, *Hy. r. ardelio*, *Hy. neglectus*, *Hy. australis*, *Hy. melanochir*, *Hy. ihi*, *Hy. quoyi*, *Hy. affinis*, *Hy. dussumieri*, *Rhynchorhamphus georgii*, *Zenarchopterus buffonis*, *Z. caudovittatus*, *Z. dispar*, *Z. gilli*, and *Z. rasori*. *Reporhamphus* is considered a synonym of *Hyporhamphus*; *Farhians* and *Ardeapiscis* are considered synonyms of *Hemiramphus*; and *Loligorhamphus* a synonym of *Rhynchorhamphus*. *Hemiramphus welsbyi* is a synonym of *He. robustus*. The eastern river garfish (*Hyporhamphus ardelio*) is reduced to a subspecies of the western river garfish (*Hy. regularis*). The New South Wales-southern Queensland population of the snub-nosed garfish (*Arrhamphus sclerolepis*) is considered a subspecies (*A. s. krefftii*) of the northern *A. s. sclerolepis*. Eight species and subspecies are endemic to Australia and the single New Zealand species of garfish is endemic there. Australian populations of widespread species are compared with extra-limital populations. Geographic variation was found in *Hy. quoyi* and *Hy. dussumieri*. Tables of meristic and morphometric characters, drawings of 11 species of garfishes, synonymies, distribution maps, summaries of biology and parasites, catch statistics and a key are included.

INTRODUCTION

The larger garfishes are important food fishes; over 1.5 million lbs were landed in Australia in 1970–71 (Anon., 1972a). Many of the species of garfishes are very similar to each other so literature records and catch statistics frequently have been based on mis-identified specimens. The purposes of this paper are to determine which species of garfishes occur in Australian and New Zealand waters, what their correct scientific names are, how they may be identified, how they vary geographically, and how Australian populations of widespread species compare with extra-limital populations of the same species. This paper is the eleventh in a series on the systematics of the Synentognathi. The work was begun and the first draft of the manuscript was completed while I was stationed at the Australian Museum in 1969–70.

MATERIALS AND METHODS

The most important sources of Australia-New Zealand garfishes, based on the number of taxa (species and subspecies), collections, and specimens are the Australian Museum (16 taxa, 25.5% of the collections, 16.2% of the specimens), the U.S. National Museum (17 taxa, 19.4% of collections, 34.4% of specimens) and C.S.I.R.O. at Cronulla (17 taxa, 19.8% of collections, 16.8% of specimens). A total of 2,310 specimens from 509 collections of the 20 taxa of Australian-New Zealand garfishes have been examined from the following 22 institutions:

AMNH	American Museum of Natural History, New York.
AMS	Australian Museum, Sydney.
ANSP	Academy of Natural Sciences, Philadelphia.
BMNH	British Museum (Natural History), London.
CSIRO	C.S.I.R.O., Division of Fisheries and Oceanography, Cronulla.
DM	Dominion Museum, Wellington.
FBQ	Fisheries Branch, Department of Primary Industries, Brisbane.
IRSNB	Institut Royal des Sciences, Naturelles de Belgique, Bruxelles.
MCZ	Museum of Comparative Zoology, Harvard University, Cambridge.
MNHN	Muséum National d'Histoire Naturelle, Paris.
NHMV	Naturhistorisches Museum, Vienna.
QM	Queensland Museum, Brisbane.
SAM	South Australian Museum, Adelaide.
SIO	Scripps Institution of Oceanography, La Jolla.
SMF	Senckenberg Museum, Frankfurt.
SMN	Staatliches Museum für Naturkunde, Stuttgart.
SU	Stanford University, specimens now at California Academy of Sciences, San Francisco.
USNM	U.S. National Museum, Washington.
VMM	Vanderbilt Marine Museum, Centerport, New York.
WAM	Western Australian Museum, Perth.
ZMH	Zoologisches Institut und Zoologisches Museum, Hamburg.
ZMUC	Zoological Museum, University of Copenhagen.

Much extra-limital material has been examined from these and many other institutions. Locality data is given here only for Australian and New Zealand specimens and for types. Meristic and morphometric data for the extra-limital material has been drawn upon for discussions, diagnoses, tables and graphs. Locality data for this material will be included in subsequent papers.

The following abbreviations are used (all measurements in mm) for the characters used in this study:

SL	Standard length, from tip of upper jaw to caudal base.
D	Dorsal fin rays. All elements counted.
A	Anal fin rays. All elements counted.
Vert	Vertebrae, counted as precaudal plus caudal equals total. Includes hypural as last vertebra.
P_1	Pectoral fin rays. All elements counted.
RGR_1	Gill rakers on first arch (total on right side).
RGR_2	Gill rakers on second arch (total on right side).
LJL	Lower jaw length, distance from tip of upper jaw to tip of lower jaw.
Hd L	Head length, distance from tip of upper jaw to posterior end of opercular membranes.
P_1L	Pectoral fin length, distance from base of uppermost pectoral ray to tip of longest ray.
P_1–P_2	Distance from base of uppermost pectoral ray to base of anteriormost pelvic ray.
P_2–C	Distance from base of anteriormost pelvic ray to caudal base. Also expressed as P_2–C extension, which is this distance extended anteriorly from base of anteriormost pelvic ray.
D base	Length of dorsal fin base from origin of fin to last ray.
A base	Length of anal fin base.
UJL	Upper jaw length, from where upper jaw bends to tip of upper jaw.
UJW	Upper jaw width, measured where upper jaw bends.

The methods of study are essentially the same as in my earlier study of eastern Atlantic Hemiramphidae (Collette, 1965). Meristic characters were analyzed by comparing frequency distributions of the various counts for different geographic regions. Where no intraspecific differences were apparent, the frequency distributions for the Australian populations of a species were combined and compared with its most closely related Australian species. Tables included in this paper either show geographic variation within a species or compare closely related species.

Several measurements were used to insure the correct identity of specimens and populations of garfishes. The initial use of this information was to see if the upper jaw was longer or shorter than wide, the dorsal fin base longer or shorter than the anal fin base, how far forward the pelvic to caudal base distance extends, etc. Because there was geographic variation in some meristic characters, the morphometric data was also analyzed geographically. Allometry seems to be relatively unimportant except for lower jaw length which undergoes several distinct growth stanzas in some species. Regressions on standard length were run, population by population, on most characters measured.

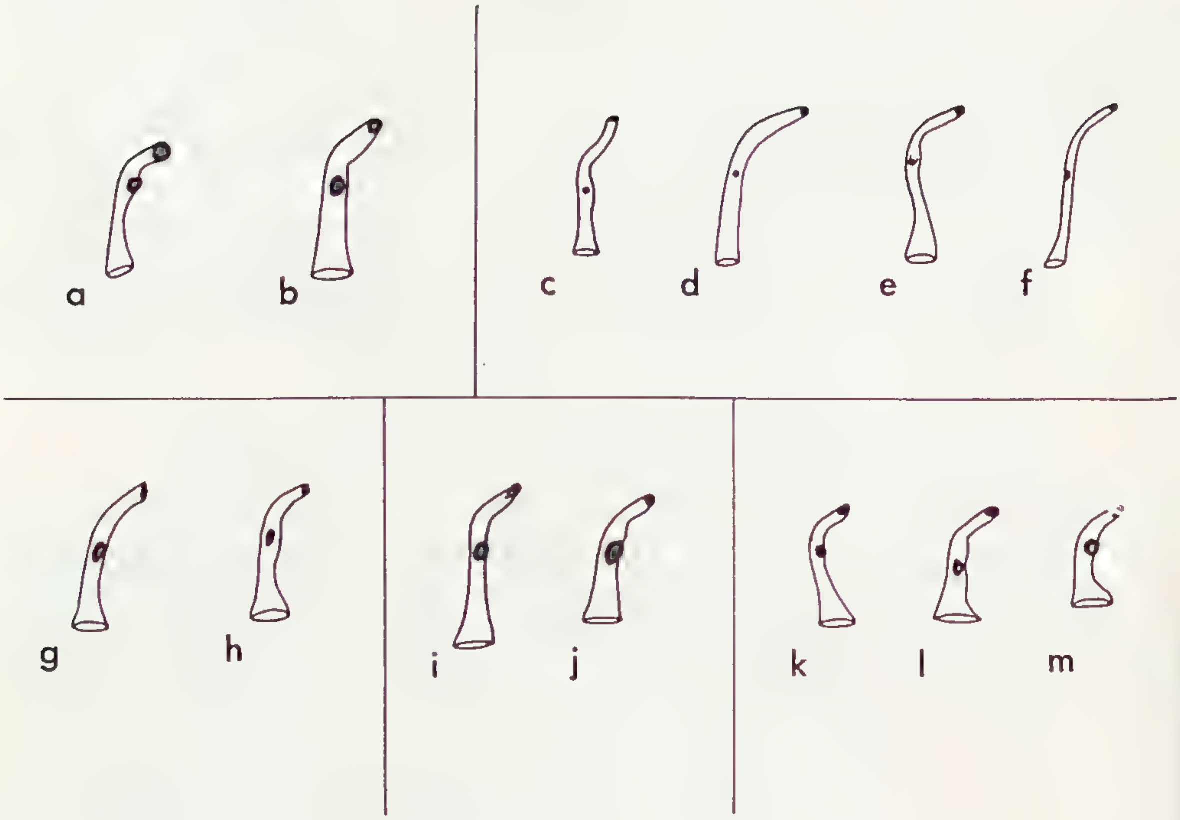


Figure 1. Preorbital canals (right side) of five species of Australian Hemiramphidae that lack a posterior branch to the canal. Not drawn to scale. a-b, *Arrhamphus sclerolepis:* a-lectotype of *A. sclerolepis*, BMNH 1862.11.15.127; b-holotype of *Hemiramphus krefftii*, "Port Jackson," N.S.W., NHMV uncat. c-f, *Rhynchorhamphus georgii:* c-holotype of *Hemiramphus georgii*, Bombay, MNHN B.1062; d-holotype of *Loligorhamphus normani*, Townsville, Qld., AMS IA.2319; e-Magnetic Is., Qld., FBQ 39; f-Cairns, Qld., FBQ 3608. g-h, *Hyporhamphus regularis ardelio:* g-lectotype of *Reporhamphus ardelio*, Clarence R., N.S.W., AMS I.12744; h-out of type series of *Hemiramphus gaimardi*, Port Jackson, N.S.W., MNHN 4590. i-j, *Hy. r. regularis:* i-lectotype of *Hemiramphus regularis*, W.A., BMNH pre-reg.; j-Swan R., W.A., AMS I.13252. k-m, *Hy. neglectus:* k-lectotype of *Hemiramphus neglectus*, E. Indies, BMNH 1866.5.2.18; l-Townsville, Qld., AMS IA.2315; m-Napier Broome Bay, W.A., CSIRO C.1751.

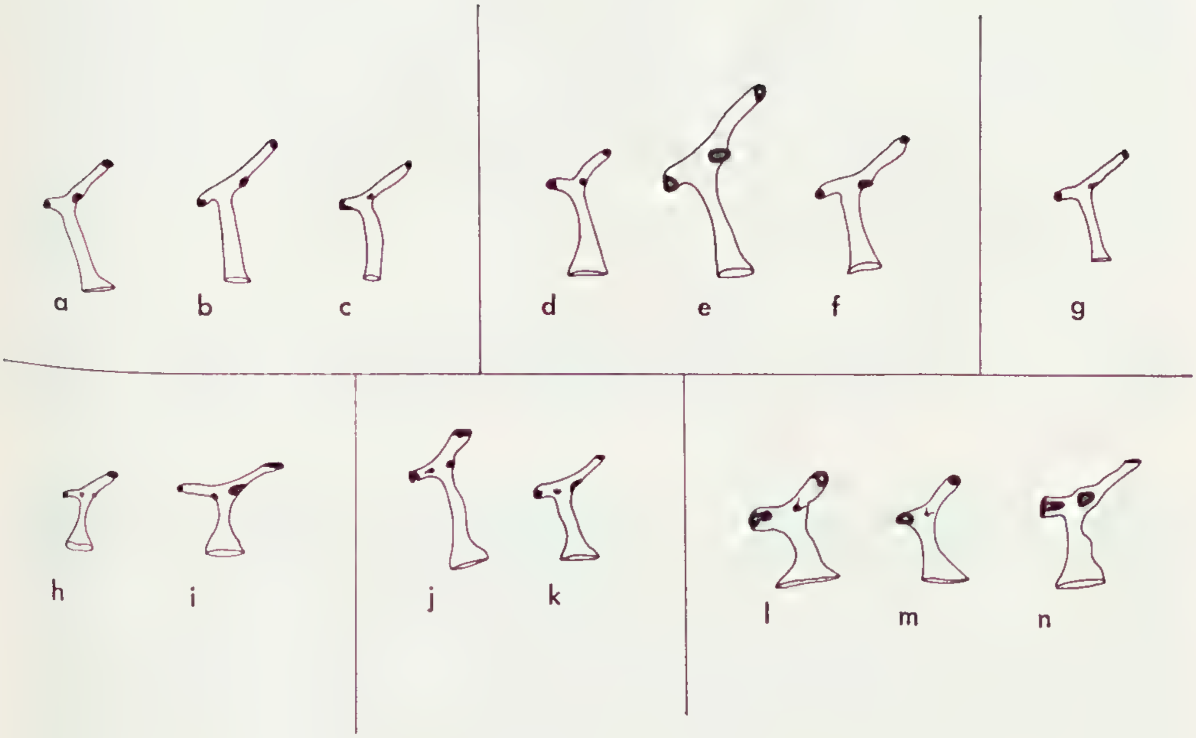


Figure 2. Preorbital canals (right side) of six species of Australian-New Zealand *Hyporhamphus*. Not drawn to scale. a-c, *Hy. australis:* a-holotype of *Hemiramphus australis*, Port Jackson, N.S.W., NHMV 5560; b-Lord Howe Is., AMS I.5568; c-Norfolk Is., AMS I.5407. d-f, *Hy. melanochir:* d-lectotype of *He. melanochir*, Adelaide, S.A., MNHN B.1066; e-Melbourne, Victoria, MCZ 8772; f-Swan R., W.A., AMS I.4199. g-*Hy. ihi*, New Zealand, DM 4865. h-i: *Hy. affinis:* h-lectotype of *He. affinis*, "South Seas," BMNH pre-reg; i-Joseph Bonaparte Gulf, N.T., CSIRO, C.1727. j-k, *Hy. dussumieri:* j-holotype of *He. dussumieri*, Seychelles, MNHN B.1063; k-One Tree Is., Great Barrier Reef, USNM 206575. l-n, *Hy. quoyi:* l-holotype of *He. quoyi*, New Guinea, MNHN B.1068; m-paralectotype of *He. gaimardi*, New Guinea, MNHN B. 1058; n-holotype of *Reporhamphus caudalis*, Cape York, Qld., AMS I.444.

Tests of differences of slopes and heights (intercepts) of pairs of regression lines were performed by analysis of covariance (Snedecor, 1956: 394–399). An unusually high value of F was selected to minimize concluding that populations were different. Only F values greater than those for P = 0.999 (table from Beyer, 1968) were considered significant and these are marked ** in the tables. If the difference between the slopes of two regression lines is significant, the difference in heights cannot be tested with this procedure. This method was used previously in studying the Belonidae of the eastern Atlantic (Collette and Parin, 1970). For some species, adjacent populations which were not significantly different were combined and retested against other populations.

The structure of the preorbital canal is an important character in the classification of the Hemiramphidae. There are generic and specific differences in this character. Within the large and complex genus *Hyporhamphus*, it is particularly useful to sort species into groups based on the presence or absence of a posterior branch to the canal (compare Fig. 1 with Fig. 2).

Six genera are recognized for the 20 taxa discussed in this paper based on my published (1965, 1966) and unpublished research and the literature: *Arrhamphus* Günther, 1866 (one species with two subspecies); *Euleptorhamphus* Gill, 1859 (one species); *Hemiramphus* Cuvier, 1829 (two species, includes *Farhians* Whitley, 1930 and *Ardeapiscis* Whitley, 1931 as synonyms); *Hyporhamphus* Gill, 1859 (nine species and subspecies, includes *Reporhamphus* Whitley, 1931 as a synonym); *Rhynchorhamphus* Fowler, 1928 (one species, includes *Loligorhamphus* Whitley, 1931 as a synonym); and *Zenarchopterus* Gill, 1863 (five species). Presentation of generic diagnoses and synonymies must await completion of further research, now in progress.

GENERAL REMARKS

Commercial Value

Garfishes have long been considered as valuable food and bait fishes in Australia and New Zealand. About 1,555,000 lbs were landed in Australia in 1970–71 (Anon., 1972a).

Data on individual species landings are not available in Queensland but a total of 128,000 lbs of garfishes was landed in 1970–71 (Anon., 1972a). This catch was probably composed largely of *Arrhamphus sclerolepis krefftii*, *Hemiramphus far*, *He. robustus*, and *Hyporhamphus quoyi*, all of which have been reported as food fishes in the State (Ogilby, 1916; Anon., 1945; Ogilby, 1954; Marshall *et al.*, 1959; Marshall, 1964; Grant, 1965). *He. far* is also important as a bait fish, especially for *Scomberomorus* (Coates, 1950).

Three species are important in New South Wales: *Arrhamphus s. krefftii*, *Hyporhamphus regularis ardelio*, and *Hy. australis* (Castelnau, 1879; Tenison-Woods, 1882; Ramsay, 1883a, 1883b; Ogilby, 1887, 1893; Cohen, 1892; Stead, 1906, 1908, 1910, 1911; Roughley, 1916, 1951, 1954; Whitley, 1962; Marshall, 1964). For *A. s. krefftii*, the catch per year has ranged from 11,581 to 116,984 lbs from 1961 to 1970; 25,414 lbs in 1970–71 (Anon., 1972b). For *Hy. r. ardelio* from 1961 to 1970, the catch has ranged from 121,164 to 192,443 lbs per year; 207,269 lbs were landed in 1970–71 (Anon., 1972b). For *Hy. australis*, the catch per year has varied from 54,070 to 119,933 lbs from 1961 to 1970; 94,731 lbs were landed in 1970–71 (Anon., 1972b). *Hy. australis* is also a sport fish (McIntyre, 1971).

The only species of garfish commonly found in the three southern most states is *Hy. melanochir* and it has long been considered an important food fish in these States—Victoria (Castelnau, 1872; Lynch, 1966); Tasmania (Johnston, 1883, 1891; Lakin, 1968–72); South Australia (Waite, 1921, 1923; Ling, 1958; Scott, 1962). In South Australia, it is one of the three most important species of inshore fishes in terms of pounds landed (Ling, 1958). The catch per year in Tasmania has varied from 13,000 lbs (1966–67) to 138,000 lbs (1962–63) over the last decade (Lakin, 1968, 1969, 1970, 1971, 1972). In 1970–71, 572,000 lbs were landed in South Australia; 427,000 lbs in Victoria; and 60,000 lbs in Tasmania (Anon., 1972a). *Hy. melanochir* and *He. robustus* are probably the most important species of garfishes in Western Australia.

Hy. ihi has been long considered a popular food fish in New Zealand (Hector, 1872; Sherrin, 1886; Phillipps, 1918, 1921, 1927b; Powell, 1947; Graham, 1953, 1956). In 1970, 261 cwt were landed with a value of $4,199 (Anon., 1971).

Biology

Little has been published on the biology of most species of Australian garfishes other than casual observations on ecology and habits. A summary of the available information about food habits, reproduction, and predators is presented here.

All the species studied appear to be largely herbivores (but none of the small estuarine species of *Zenarchopterus* has yet been examined). The sea grass *Zostera* was found in more than 80% of the gut contents of specimens of *Hyporhamphus regularis ardelio* from Lake Macquarie, N.S.W., with less than 20% containing filamentous algae or diatoms (Thomson, 1959b). In Lake Macquarie, *Hy. australis* feeds primarily on *Zostera* and crustaceans, both categories present in over 80% of specimens examined by Thomson (1959b). Thomson (1957a) also studied the food habits of *Hy. melanochir*. Of 301 specimens taken throughout the year from several Western Australia localities, 70% contained the sea grass *Zostera;* 36% filamentous green algae such as *Enteromorpha*, *Cladophora*, and *Chaetomorpha;* 25% diatoms, usually mixed with algal filaments; 6% chironomid larvae; and 4% polychaetes. No seasonal variation was found. Graham (1939a) concluded that the chief food of *Hy. ihi* in Otago Harbour, N.Z., was *Zostera marina* (eel-grass), *Ulva lactuca* (sea lettuce), and various other sea-weeds and algae found on the mudflats. Although Thomson and Anderton (1921) and Thomson (1931) recorded worms (such as *Harmothoea*, *Amphitrite*, and *Eunice*) and small crustaceans in the diet, these may have been taken accidently (Graham, 1939a, 1956). In addition, data is available on the food habits of two Australian species from India. Talwar (1962) found that 70% of the gut contents of *He. far* and *Hy. quoyi* contained sea grasses (*Cymodocea*) along with 10% green algae (such as *Cladophora* and *Chaetomorpha*), 5% diatoms, and 5% polychaetes (*Nereis* and *Perinereis*).

Information is available on reproduction of two species of sea garfishes, *Hy. melanochir* and *Hy. ihi*. For *Hy. melanochir*, the spawning period, as deduced from ripe ovaries, is in the spring and summer, October to February in Western Australia (Thomson, 1957b), October to March in South Australia (Ling, 1958). The minimum size at first maturity in Western Australia is 245 mm fork length for males, 246 mm for females (Thomson, 1957b). In South Australia, most spawners were at least two or three years old (Ling, 1958). Fecundity was calculated by Thomson (1957b) as 1,280–3,000 eggs with a diameter of 1.5 mm when ripe. *Hy. melanochir* eggs are large and clear and have filaments with which they become attached to aquatic vegetation. Based on otoliths, *Hy. melanochir* reaches an age of at least VIII in South Australia (Ling, 1958).

Ripe *Hy. ihi* appear in December (Thomson, 1932), January (Thomson and Anderton, 1921), and February and March (Benham, 1938). The eggs are 2.5–2.6 mm in diameter, have many small oil globules, and are covered with long transparent filaments that attach the eggs to the vegetation (Thomson and Anderton, 1921; Thomson, 1932; Graham, 1939b). In the laboratory, the eggs hatch in 36–45 days (Thomson, 1932; Graham, 1939b). Development of the larvae up to four days has been figured by Graham (1939b, 1956).

Predators of garfishes include a number of species of fishes, sea birds, and man. Up to 30% by volume of the stomach contents of the large black cormorant, *Phalacrocorax carbo novaehollandiae* in the Gippsland Lakes, Vict., consisted in some months, of *Hy. r. ardelio* (Mack, 1941). Known natural predators of *Hy. melanochir* include the ruff, *Arripis georgianus* and the red-tailed tropic-bird, *Phaethon rubicauda* (Thomson, 1957a; Tarbottom, 1968). Predators of *Hy. ihi* include red cod, *Physiculus bachus;* kahawai, *Arripis trutta;* and red gurnard, *Currupiscis kumu* (Graham, 1939a, 1956; Baker, 1971).

Parasites

While examining Australian garfishes, copepods and isopods were removed. Seven species of copepods were identified by Dr Roger F. Cressey (USNM): Ergasilidae — *Ergasilus semicoleus* Cressey, *Paraergasilus* sp.; Bomolochidae — *Nothobomolochus denticulatus* (Bassett-Smith), *Bomolochus bellones* Burmeister; Caligidae— *Pseudopetalus formicoides* (Redkar, Rangnekar, and Murti); Anthosomatidae— *Lernanthropus belones* Krøyer; and Lernaeidae—*Lernaeenicus sayori* Yamaguti. After completion of further studies on the Hemiramphidae Dr Cressey and I plan to treat the copepod fauna of the family as we recently did for the Belonidae (Cressey and Collette, 1970).

Cymothoid isopods have been given to Dr Thomas E. Bowman (USNM) for subsequent study. At least some of the isopods fit the description of *Irona melanosticta* Schiodte and Meinert but there are taxonomic problems at the generic as well as the specific levels according to Mr David M. Damkaer (pers. comm.) who made a preliminary study of the material.

Parasites known from Australian garfishes, both from the literature and from Dr Cressey's identification of material collected during this study are listed by host in the same order as the species of garfishes are treated in the main part of this paper.

Arrhamphus s. sclerolepis: Lernaeenicus sayori from Townsville, Qld (female attached near dorsal fin of CSIRO uncat.); *Ergasilus semicoleus* from Port Bradshaw, N.T. (three females from gill filaments of USNM 173776); *Paraergasilus* sp. from Port Hedland, W.A. (six females under opercles of AMNH 40003); Caligidae sp. from SE. Gulf of Carpentaria (juvenile attached to dorsal fin of AMS I.1552-006). *A. s. krefftii: Lernanthropus belones* from Gladstone, Qld. (female, male, and immature from gill filaments of USNM 294075) and *Lernanthropus* sp. from Moreton Bay, Qld. (4 males from CSIRO C.2982).

Hemiramphus far: Lernanthropus sp. from Groote Eylandt, N.T. (male from the gill filaments of USNM 173777). *He. robustus: Nothobomolochus denticulatus* from Townsville, Qld. (2 females under opercles of QM I.6593-4) and *Lernaeenicus* sp. from Townsville, Qld. (female imbedded in belly anterior to pelvic fins of QM I.6594).

Hyporhamphus regularis ardelio: Bomolochus bellones from Sydney (female under gill cover, SU 8318) and Sussex Inlet, N.S.W. (six females between opercle and gills of three specimens, USNM 206570; *Lernaeenicus sayori* (one female imbedded in the side of USNM 176889). *Hy. neglectus: Lernaeenicus sayori* from Port Essington, N.T. (female in pharyngeal cavity of CSIRO C.1747) and *Pseudopetalus formicoides* from Port Essington (female imbedded in left nasal fossa of CSIRO C.1747) and Port Bradshaw, N.T. (female from USNM 173792). *Hy. australis: Bomolochus bellones* from under the opercles of specimens from Jervis Bay, (female from CSIRO uncat.) and Port Stephens (four females from USNM 206581); *Lernanthropus belones* from the gill arches of five specimens from Port Stephens (five females and three males from USNM 206581); and *Lernanthropus* sp. from Sydney (male from SU 20981).

Two species of copepods were common on *Hy. melanochir*. *Lernaeenicus sayori* from Mangles Bay, W.A. (USNM 206569); Bunbury, W.A. (WAM P–6129); Mandurah, W.A. (USNM 206587); Cockburn Sound, W.A. (AMNH 40004); and Adelaide, S.A. (USNM 206586); a total of 12 females imbedded in the sides, belly, caudal peduncle, under the pectoral girdle, behind the lower jaw, and in the nasal fossa of 12 specimens. *Bomolochus bellones*, 62 females and 3 males, from under the opercles of 27 fish from Rottnest Is., W.A. (WAM P–13408–13); Fremantle, W.A. (WAM P–308); Whitford Beach, W.A. (WAM P–2575); Cockburn Sound, W.A. (AMNH 40004); Mandurah, W.A. (USNM 206587); Albany, W.A. (CSIRO C.2528); Adelaide, S.A. (ZMK P–341781–9); Kangaroo Is., S.A. (CSIRO uncat.); and Tamar R., Tas. (USNM 206557).

There are two literature reports of copepods from Australian garfishes, both from *Hy. melanochir*. Heegaard (1962: 185) reported a female *Lernaeenicus hemiramphi* Kirtisinghe from the eye of a specimen from St Vincent Gulf, S.A. Kabata (1966: 568) reported 13 females and 2 males of the euryphorid *Gloiopotes huttoni* (Thomson) from Adelaide. *Gloiopotes* is restricted to hosts in the families Istiophoridae, Xiphiidae, and Scombridae and *G. huttoni* is known primarily from istiophorid hosts with one record from *Xiphius* (Cressey, 1967). Both Dr Cressey and I feel certain some sort of mix-up has occurred in the host data for Kabata's record.

Hale (1926, 1929) has reported the cymothoid isopod *Irona melanosticta* from under the gill covers of South Australian specimens from Port Victor, the Gulf of St Vincent, and Port Adelaide. Isopods were collected from a number of the specimens examined for this paper but their identity is still in question.

Hyporhamphus ihi. No copepods were collected from this species and none are reported in the literature. Numerous cymothoid isopods were removed from the *Hy. ihi* examined for this study but they have not been positively identified. Several different isopods have been reported from New Zealand garfishes. Thomson (1889) found a single specimen of *Ceratothoa lineata* Miers (= *Codonophilus lineatus*) from a garfish from Nelson. Powell (1947) listed *Livoneca novaezelandiae* (Filhol) as common in the mouths of *Hy. ihi*. Hurley (1961) considered *C. novaezelandiae* a synonym of *C. imbricatus* (Fabricius). Stephenson (1969) discussed a large sample (164 females, 54 males, 21 juveniles) of *Irona melanosticta* from the Bay of Islands and Hauraki Gulf. *Livoneca* does not occur on *Hy. ihi* according to Stephenson (1969 and pers. comm.). An acanthocephalan, *Micracanthocephalus hemirhamphi*, has been described from the stomach of *Hy. ihi* from Otago Bay by Baylis (1944: 469–471).

Hyporhamphus quoyi: Lernanthropus belones from the gills of a specimen from Groote Eylandt, N.T. (female and three males from USNM 173785); *Nothobomolochus denticulatus* from under the opercles of seven fish from six N.T. localities: Darwin (two females from CSIRO C.1724 and one female, USNM 173779), Port Bradshaw (six females, USNM 173787), Pellew Is. (female, ANSP 86430), Groote Eylandt (two females, USNM 173784), and Yirrkala (female, USNM 173786). *Hy. affinis: Lernaeenicus sayori* female imbedded laterally anterior to the anal fin origin in a specimen from Joseph Bonaparte Gulf, N.T. (CSIRO C.1727). *Hy. dussumieri: Pseudopetalus formicoides* female attached under the gill cover of a specimen from Cairns, Qld. (AMS IA.2946).

Zenarchopterus buffonis: Ergasilus semicoleus from Darwin, N.T. (about 20 females from the gill filaments of USNM 173767). *Z. caudovittatus:* Ergasilidae from Arnhem Land, N.T. (female from gill filaments of USNM 173769).

Zoogeography

Based on their distribution patterns in Australia, the 20 taxa of garfishes can be divided into four groups: tropical freshwater-estuarine (the five species of *Zenarchopterus*, none of which is endemic); southwest and southeast estuarine endemic (*Hyporhamphus r. regularis* and *Hy. r. ardelio*); temperate marine endemic (*Hy. melanochir*, *Hy. australis*, and *Hy. ihi*); and tropical marine (the remaining ten taxa, three of which are endemic). Whitley has published zoogeographic maps of the marine provinces of Australia and New Zealand (1932b) and of the freshwater "fluvifaunulae" of Australia (1959a) based on the work of a long series of previous investigators. Although the borders and definitions of some of these regions have been modified by subsequent workers, (for example, see George, 1969 and included references), it may be instructive to compare the distribution of Australian garfishes with Whitley's maps.

(1) The five species of the freshwater and estuarine genus *Zenarchopterus* are found in the tropical northern part of Australia and all have ranges which extend outside of the continent. Three species are widespread outside of Australia, to the East Indies and Philippines (*Z. buffonis*), New Guinea and New Caledonia (*Z. dispar*), Madagascar to Guam and Fiji (*Z. gilli*). Their distributional patterns within Australia can be compared with the freshwater fluvifaunulae of Whitley (1959a). Three species occupy the northern (Leichhardtian) and northeastern (Jardinean) fluvifaunulae. The other two species are restricted to the Leichhardtian Fluvifaunule in Australia but extend further north as well, to New Guinea (*Z. caudovittatus*) or the Celebes (*Z. rasori*).

(2) Southwest and southeast estuarine endemic (Fig. 12). *Hyporhamphus r. regularis* inhabits estuaries and rivers of the southwestern fluvifaunule (Vlaminghian) and is replaced in New South Wales and eastern Victoria (Lessonian) by *Hy. r. ardelio.*

(3) Temperate marine endemic (Fig. 18). Three closely related allopatric species: *Hy. melanochir* inhabits the cold temperate Flindersian (Perth, W.A. to Vict.) and Maugean (Tas.) provinces; *Hy. australis* replaces it in the Peronian (N.S.W. to southern Qld.) Province and also in the Phillipian Province (Lord Howe and Norfolk Is.); and *Hy. ihi* is found in three provinces of the Neozelanic Region (Cookian—North Is., Forsterian—South Is., and Moriorian—Chatham Is.). Whitley (1932b) included the Phillipian Province in the Neozelanic Region based on previous malacological work but the presence of *Hy. australis* and other evidence (J. C. Briggs, pers. comm.) indicates that the closest relationship of these islands is to eastern Australia, not New Zealand.

(4) Tropical marine. The distribution of the ten taxa of this group is centered in the northern tropical part of the continent, the Dampierian Province, and extends south along east and west coasts for varying distances depending on the species. The five most tropical species are restricted to the northern part of the Dampierian plus the Banksian and Solanderian provinces. The Australian range of *Hyporhamphus affinis* is restricted to the Dampierian Province from Shark Bay, W.A. to Joseph Bonaparte Gulf, Timor Sea. *Hemiramphus far* (Fig. 9) and *Hy. neglectus* (Fig. 12) extend south to Broome on the west coast and to Palm Is. and the Cumberland Is., respectively, on the east coast. However, *Hy. neglectus* is confined to the more turbid coastal waters of eastern Queensland (Whitley's Banksian Province) while *He. far* is mostly present around the Barrier Reef (Solanderian Province). *Hy. dussumieri* has been taken in a couple of Arnhem Land and Western Australia collections but is most abundant in the Solanderian Province. Only five Australian specimens of *Rhynchorhamphus georgii* have been taken, from eastern Queensland and the Northern Territory.

The remaining five taxa all extend further south. *Arrhamphus s. sclerolepis* (Fig. 6) and *Hy. quoyi* reach Shark Bay on the west coast, a more reasonable limit to the Dampierian fauna than Geraldtown as mapped by Whitley (1932b). On the east coast, both inhabit the Banksian Province, south to Bowen and Lindeman Is. for *A. s. sclerolepis* and south to Yamba Bay, N.S.W. for *Hy. quoyi*. The pair of species extending the farthest south is *He. robustus* (Fig. 9) and *Euleptorhamphus viridis* (Fig. 6), reaching at least to Perth on the west coast and Sydney on the east coast. There are a few records even further south, of *E. viridis* to Albany, W.A. and *He. robustus* to Long Is. in the Hogan Group north of Tasmania. *A. sclerolepis krefftii* (Fig. 6) crosses the border between the tropical Banksian and the temperate Peronian provinces in extending from about Rockhampton, Qld., south to at least Laurieton, N.S.W.

KEY TO AUSTRALIAN AND NEW ZEALAND SPECIES OF GARFISHES

1. Nasal papilla elongate and pointed, extending well out of nasal fossa (Fig. 3 middle); caudal fin rounded or truncate; anal rays and sometimes dorsal rays of males specialized, sometimes greatly elongate .... *Zenarchopterus* 16

   Nasal papilla rounded or fan-shaped, mostly confined to the nasal fossa (Fig. 3 top); caudal fin moderately to deeply forked; fin rays of males not modified... 2

2. Lower jaw very short, less than one-fifth head length; pelvic fins inserted far anteriorly, P_2–C extension falls very far anterior, on upper or lower jaw .... *Arrhamphus sclerolepis* 3

   Lower jaw longer, no shorter than half head length; pelvic fins placed further posteriorly, P_2–C extension falling no further forward than preorbital 4

3. Gill-rakers on first arch 21–25, usually more than 22; total gill-rakers on first plus second arches 37–45; vertebrae 45–48; lower jaw longer in specimens over 100 mm SL (Fig. 4) .... *A. sclerolepis sclerolepis*

   Gill-rakers on first arch 18–23, usually less than 22; total gill-rakers on first plus second arches 33–39, usually 38 or less; vertebrae 48–50; lower jaw shorter in specimens over 100 mm SL (Fig. 4) .. *A. sclerolepis krefftii*

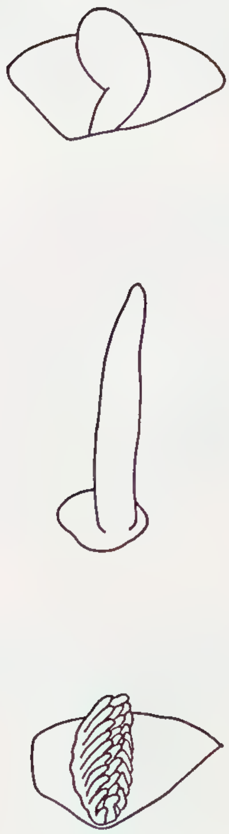


Figure 3. Diagrams of nasal papillae in (from top to bottom): *Hyporhamphus*, *Zenarchopterus*, and *Rhynchorhamphus*.

4\. Pectoral fin very long, only 8–8½ rays; body strongly compressed and band-like; D 21–25; A 21–24 .... *Euleptorhamphus viridis*

Pectoral fin much shorter, 10–14 rays; body rounded or only slightly compressed; D 12–18; A 10–20 5

5\. Triangular part of upper jaw naked; preorbital ridge absent .. *Hemiramphus* .. 6

Triangular part of upper jaw covered with small scales; preorbital ridge present 7

6\. Four–six dark blotches on sides of body; A 10 or 11 .... *He. far*

One or no dark lateral blotches; A usually 12 or 13 .... *He. robustus*

7\. Upper jaw large and dome-shaped; nasal papilla fimbriate (Fig. 3 bottom); first arch gill-rakers 52–60 .... *Rhynchorhamphus georgii*

Upper jaw flat or only slightly arched; nasal papilla rounded or fan-shaped, not fimbriate (Fig. 3 top); first arch gill-rakers 19–46 .... *Hyporhamphus* 8

8\. Preorbital canal with posterior branch (Fig. 2) 9

Preorbital canal without posterior branch (Fig. 1) 14

9\. Head length much greater than beak length in adults, slightly greater in juveniles .... *Hy. quoyi*

Head length about equal to or less than beak length 10

10\. Preorbital canal narrow, usually slightly expanded at ventral pore; posterior branch of preorbital canal usually on a straight line with anterior branch (Fig. 2, a–g); A rays usually 18 or more 11

Preorbital canal wider, greatly expanded at ventral pore; posterior branch forming an obtuse angle with anterior branch (Fig. 2, h–k); A usually 17 or less 13

11\. First arch gill-rakers usually 34 or more; second arch gill-rakers usually 27 or more .... *Hy. australis*

First arch gill-rakers usually 33 or less; second arch gill-rakers usually 26 or less 12

12\. Pelvic fins placed further anteriorly, P_2–C extension usually falls on pectoral base or opercle .... *Hy. ihi*

Pelvic fins placed further posteriorly, P_2–C extension usually falls on adpressed pectoral fins .... *Hy. melanochir*

13\. First arch gill-rakers usually 35 or less; second arch gill-rakers usually 24 or less; preorbital length much greater than upper jaw length .... *Hy. affinis*

First arch gill-rakers usually 36 or more; second arch gill-rakers 26 or more; upper jaw longer than preorbital length .... *Hy. dussumieri*

14\. Second arch gill-rakers usually 23 or fewer; first arch gill-rakers 31 or fewer .... *Hy. neglectus*

Second arch gill-rakers usually 23 or more; first arch gill-rakers 31 or more .... *Hy. regularis* 15

15. Lower jaw shorter (see Fig. 10); Western Australia .... *Hy. r. regularis*

Lower jaw longer (see Fig. 10); S. Queensland to Victoria ...... *Hy. r. ardelio*

16. Upper jaw much longer than wide; width divided by length 0.6–0.7. Pectoral fin nearly as long as head; head length divided by pectoral length 0.9–1.0. Lower jaw shorter than head; head length divided by lower jaw length 1.3–1.8 .... *Zenarchopterus caudovittatus*

Upper jaw not as long; width divided by length 0.8–1.4. Pectoral fin much shorter than head length; head length divided by pectoral length 1.3–6.1. Lower jaw longer than head; head length divided by lower jaw length 0.5–0.8 17

17. Upper jaw slightly longer than wide; width divided by length 0.8–0.9. Anal rays 8 or 9 .... *Z. rasori*

Upper jaw usually wider than long; width divided by length 0.9–1.4. Anal rays 10–14 18

18. A dark brown line along midline of snout; dorsal and anal rays of male modified but not reaching beyond caudal base .... *Z. buffonis*

Snout unicolor brown; one or two dorsal rays of males thickened and elongate; one or two anal rays of males greatly developed, reaching past caudal base 19

19. Sixth and seventh anal rays of males greatly elongated; two dorsal rays (of 3rd, 4th, 5th) of males modified; D 11 or 12 .... *Z. dispar*

Sixth anal ray of males greatly elongated; 4th and 5th dorsal rays of males modified; D 10 or 11 .... *Z. gilli*

SPECIES ACCOUNTS

Arrhamphus sclerolepis Günther

Snub-nosed Garfish

Figs 4–6, Tables 1–2

Diagnosis

A. sclerolepis differs from all other Australian garfishes in its very short lower jaw (Fig. 5) which extends only 1.5–11.0 mm beyond the upper jaw throughout the size range (17.9 to 277 mm SL). *Arrhamphus* shares this greatly reduced lower jaw with two other monotypic allopatric genera: *Melapedalion breve* (Seale) in the Philippines and *Chriodorus atherinoides* Goode and Bean in the western Atlantic. The lower jaw is even shorter in *Melapedalion* and it is essentially non-existent in adult *Chriodorus*. *M. breve* has been placed in *Arrhamphus* by some workers but it differs significantly in many characters: prominent posterior branch to preorbital canal; prominent black tips to upper and lower caudal lobes and to anterior dorsal and anal fin lobes; pelvic fins further posterior so that P_2–C extension falls on orbit to preopercle; more gill-rakers; more vertebrae; etc. *Chriodorus* is similar to *Arrhamphus* in all these characters except that the pelvic fins are placed slightly further posteriorly, but not as far as in *Melapedalion*. The generic relationships of *Chriodorus* and *Arrhamphus* will be treated further in a subsequent paper.

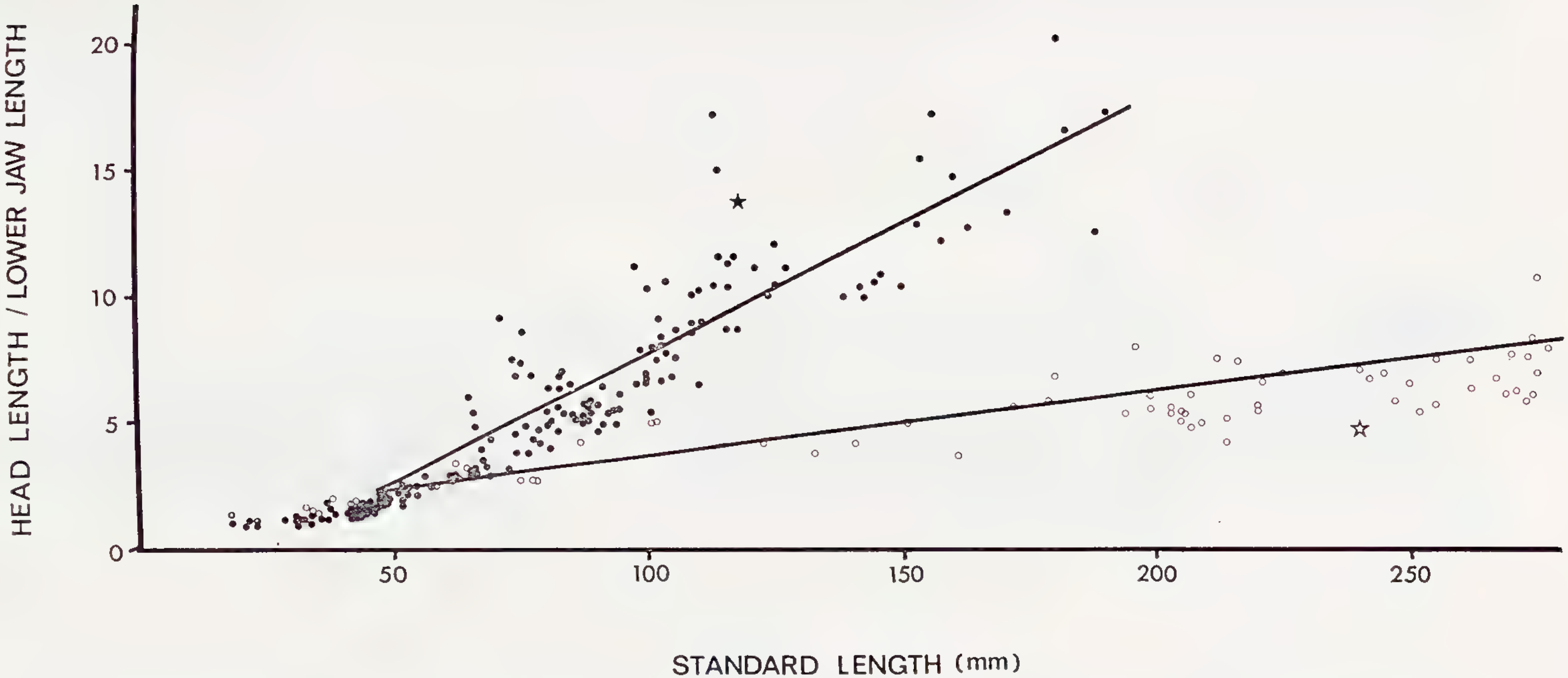


Figure 4. Change of ratio of head length divided by lower jaw length with size in the two subspecies of *Arrhamphus sclerolepis*. Open circles indicate the southeastern subspecies, *A. s. krefftii;* open star the holotype, NHMV uncat. Dots indicate the northern subspecies, *A. s. sclerolepis;* closed star the lectotype, BMNH 1862.11.15.127.

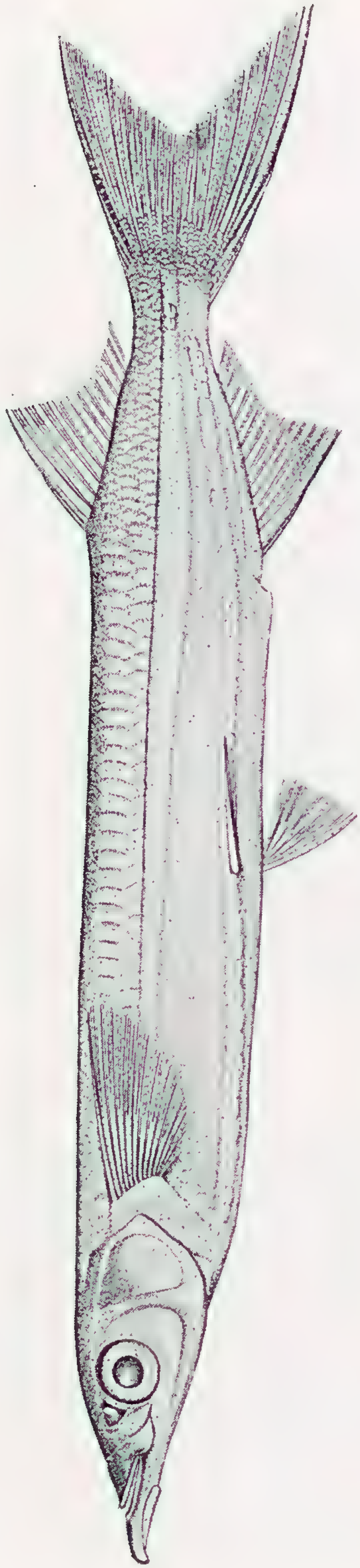


Figure 5. *Arrhamphus sclerolepis krefftii*, USNM 206571, 220 mm SL, Clarence River, N.S.W.

Description

Preorbital canal a simple tube with a pore at each end and another in the middle (Fig. 1, a–b). Dorsal rays 13–16, usually 14–15; anal rays 14–17, usually 15–16; pectoral rays 12–14, usually 13. Vertebrae (28–32) + (17–19) = 45–50. Gill-rakers on first arch (5–8) + (14–18) = 18–25; on second arch (2–5) + (11–16) = 15–20. Lower jaw short, not increasing much with the growth of the fish. Head length divided by lower jaw length increases from 1.0–2.2 at small sizes (18–50 mm SL) to 5–20 at larger sizes (Fig. 4, and see geographic variation). Pelvic fins inserted very far anteriorly, much nearer pectoral fin origin than caudal base; P_2–C about twice P_1–P_2; P_2–C extension falls on upper jaw to beyond tip of lower jaw. Dorsal and anal fin bases of about equal length, the dorsal fin base usually a little longer; dorsal base divided by anal base 0.93–1.18.

Geographic Variation

Significant meristic and morphometric geographic variation exists in *Arrhamphus sclerolepis* (Tables 1–2). The meristic variation at first seemed to be clinal as it is in the number of gill-rakers in *Hyporhamphus quoyi*. However, dividing the specimens from the east coast of Australia into northern (MacKay to Cooktown, Qld.) and southern (Rockhampton south into New South Wales) populations clearly demonstrated that there are two groups of populations. The northern group extends across the top of Australia and down the coast of Western Australia.

The southeast population differs from the northern populations in having fewer gill-rakers on the first and second arches, more anal fin rays, and more vertebrae (Table 1). By adding the number of gill-rakers on the first and second arches, specimen by specimen, 94.4% of the southeast population can be separated from 96.8% of the northern populations. Correlated with the higher number of anal fin rays (modally 16 instead of 15), there are more vertebrae in the southeast population (48–50) than in those from the Gulf of Carpentaria, Northern Territory, and Western Australia (45–48). X-raying specimens was difficult in Australia so I have good data for only four populations. The number of dorsal and pectoral rays is relatively constant from population to population, usually 14 and 13, respectively.

Morphometrically each of the five populations differed from adjacent populations in some of the six characters analyzed (Table 2). Plotting the ratio of head length divided by lower jaw length against standard length shows two distinct groups of specimens at sizes over 100 mm SL (Fig. 4). The lower jaw remains proportionately longer in the southeast population (up to 10.9 times in head length) whereas the lower jaw becomes proportionately much shorter in all the northern populations (up to 20.2 times). In addition, the southeast population apparently reaches a greater length than the northern populations (277 vs. 218 mm SL).

The other morphometric differences are of less importance but do indicate that each population has diverged to some extent from adjacent populations. Each of the four northern populations differs significantly from the adjacent ones in the heights of regression of head length on standard length (Table 2). The N. Queensland population differs significantly from the Gulf of Carpentaria population in the slopes of regression of the length of the anal fin base. However, when N. and S. Queensland are combined and tested against the combined Gulf of Carpentaria, Darwin, and Western Australia group, neither slopes nor heights are significantly different ($F = 2.69, 1.20$). The Western Australia population is significantly different from the Darwin population in the heights of regression of the P_1–P_2 distance. However, when the populations to the east of Darwin are combined with Darwin and retested against the Western Australian population, again neither slopes nor heights are significantly different ($F = 1.92, 0.78$).

Table 1. **Number of fin rays, gill-rakers, and vertebrae in populations of** *Arrhamphus sclerolepis* **(* for New South Wales indicates count of holotype of** *He. krefftii*, *** for types indicates lectotype of** *A. sclerolepis*)

Locality	Fin Rays														
	Dorsal						Anal						Pectoral		
	13	14	15	16	N	$\bar{x}$	14	15	16	17	N	$\bar{x}$	12	13	14
A. s. krefftii															
New South Wales ..	..	23	16*	2	41	14.49	..	3*	30	8	41	16.12	3*	31	7
SE. Queensland ..	2	14	5	..	21	14.14	..	4	14	3	21	15.95	1	8	4
A. s. sclerolepis															
NE. Queensland ..	..	42	12	..	54	14.22	1	34	18	1	54	15.35	7	15	..
Gulf of Carpentaria .	4	21	15	..	40	14.28	6	30	4	..	40	14.95	2	17	1
Northern Territory .	2	17	16	..	35	14.40	5	23	7	..	35	15.06	..	18	3
Western Australia .	9	35	5	..	49	13.92	3	36	10	..	49	15.14	1	16	3
Types	..	2*	..	..	2	14.0	..	..	2*	..	2	16.0	..	2*	..
New Guinea	..	..	2	..	2	15.0	..	..	2	..	2	16.0	..	2	..

Table 1—*continued*

Locality	Gill-Rakers: First Arch 18	19	20	21	22	23	24	25	N	$\bar{x}$	Second Arch 15	16	17	18	19	20	N	$\bar{x}$
A. s. krefftii																		
New South Wales ..	2	11	12	16*	1	..	..	..	42	20.07	10	17*	14	1	..	..	42	16.14
SE. Queensland ..	..	2	1	5	3	1	..	..	12	21.00	4	5	3	..	..	..	12	15.92
A. s. sclerolepis																		
NE. Queensland ..	..	..	..	1	6	7	13	2	29	23.31	..	2	8	11	8	..	29	17.86
Gulf of Carpentaria ..	..	..	..	2	5	12	16	5	40	23.43	..	..	4	15	16	5	40	18.55
Northern Territory ..	..	..	..	1	1	9	12	2	25	23.52	..	..	3	10	10	2	25	18.44
Western Australia ..	..	..	..	1	7	12	6	2	28	23.04	..	1	4	13	7	3	28	18.25
Types	..	..	..	..	..	1	1*	..	2	23.5	..	..	..	1	1*	..	2	18.5
New Guinea	..	..	..	1	..	..	1	..	2	22.5	..	1	1	..	..	..	2	16.5

Locality	Total Gill-Rakers on First and Second Arches 33	34	35	36	37	38	39	40	41	42	43	44	45	N	$\bar{x}$	Total Vertebrae 45	46	47	48	49	50	N	$\bar{x}$
A. s. krefftii																							
New South Wales ..	1	5	7	10	11*	7	1	..	..	..	..	..	..	42	36.19	..	..	..	2	14	3	19	49.05
SE. Queensland ..	..	1	1	3	2	3	2	..	..	..	..	..	..	12	36.92	..	..	..	..	1	1	2	49.50
A. s. sclerolepis																							
NE. Queensland ..	..	..	..	..	..	1	4	3	8	6	6	1	..	29	41.24	..	..	1	2	..	..	3	47.67
Gulf of Carpentaria ..	..	..	..	..	..	1	2	4	8	10	9	4	2	40	41.93	..	2	26	6	..	..	34	47.12
Northern Territory ..	..	..	..	..	..	..	1	3	5	6	8	1	1	25	41.96	..	2	20	4	..	..	26	47.08
Western Australia ..	..	..	..	..	1	..	2	6	7	6	4	..	2	28	41.29	1	26	17	..	..	..	44	46.36
Types	..	..	..	..	..	..	..	..	1	..	1*	..	..	2	42.0	..	..	1*	..	..	..	1	47.0
New Guinea	..	..	..	..	..	1	..	1	..	..	..	..	..	2	39.0	..	..	..	1	..	..	1	48.0

Table 2. Comparison of regression equations and F values for slopes and heights of five morphometric characters and one ratio for five populations of *Arrhamphus sclerolepis* (= Significant at 99.9% level)**

	Regression equations Y =				
Character	New South Wales—S. Queensland	N. Queensland	Gulf of Carpentaria	Darwin	Western Australia
Head length	0.2164X + 1.784	0.2198X + 1.932	0.2163X + 3.522	0.2150X + 2.440	0.2008X + 4.486
P_1–P_2	0.2841X − 1.616	0.2748X − 1.425	0.2842X − 3.406	0.2592X − 0.262	0.2643X + 0.120
P_2–C	0.5173X − 0.443	0.5410X − 2.034	0.5460X − 2.350	0.5331X − 1.470	0.5470X − 2.858
Base dorsal fin	0.1505X − 0.716	0.1623X − 1.116	0.1399X + 1.773	0.1508X + 0.398	0.1608X − 0.348
Base anal fin	0.1439X + 0.181	0.1484X − 0.575	0.1246X + 2.409	0.1354X + 0.871	0.1461X + 0.275
Head length / Lower jaw length	0.0217X + 1.358	0.0959X − 2.429	0.1069X − 2.783	0.1155X − 3.876	0.0814X − 0.503

	F values							
	New South Wales—S. Queensland vs. N. Queensland		N. Queensland vs. Gulf of Carpentaria		Gulf of Carpentaria vs. Darwin		Darwin vs. Western Australia	
Character	*Slopes*	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*
Head length	0.221	1.08	0.185	20.72**	0.012	19.42**	5.36	17.14**
P_1–P_2	0.169	0.357	0.497	4.52	4.23	1.67	0.453	14.99**
P_2–C	2.80	1.90	0.138	5.13	1.50	2.20	2.22	0.438
Base dorsal fin	2.29	3.72	10.26	1.31	2.52	0.965	3.91	0.849
Base anal fin	0.337	0.210	12.98**	0.780	1.84	2.48	4.90	5.66
Degrees of freedom	1, 66–68		1, 39–40		1, 38		1, 43	
Head length / Lower jaw length	395**	(13.67)	1.25	3.62	0.360	0.542	7.59	3.34
Degrees of freedom	1, 123		1, 106		1, 76		1, 67	

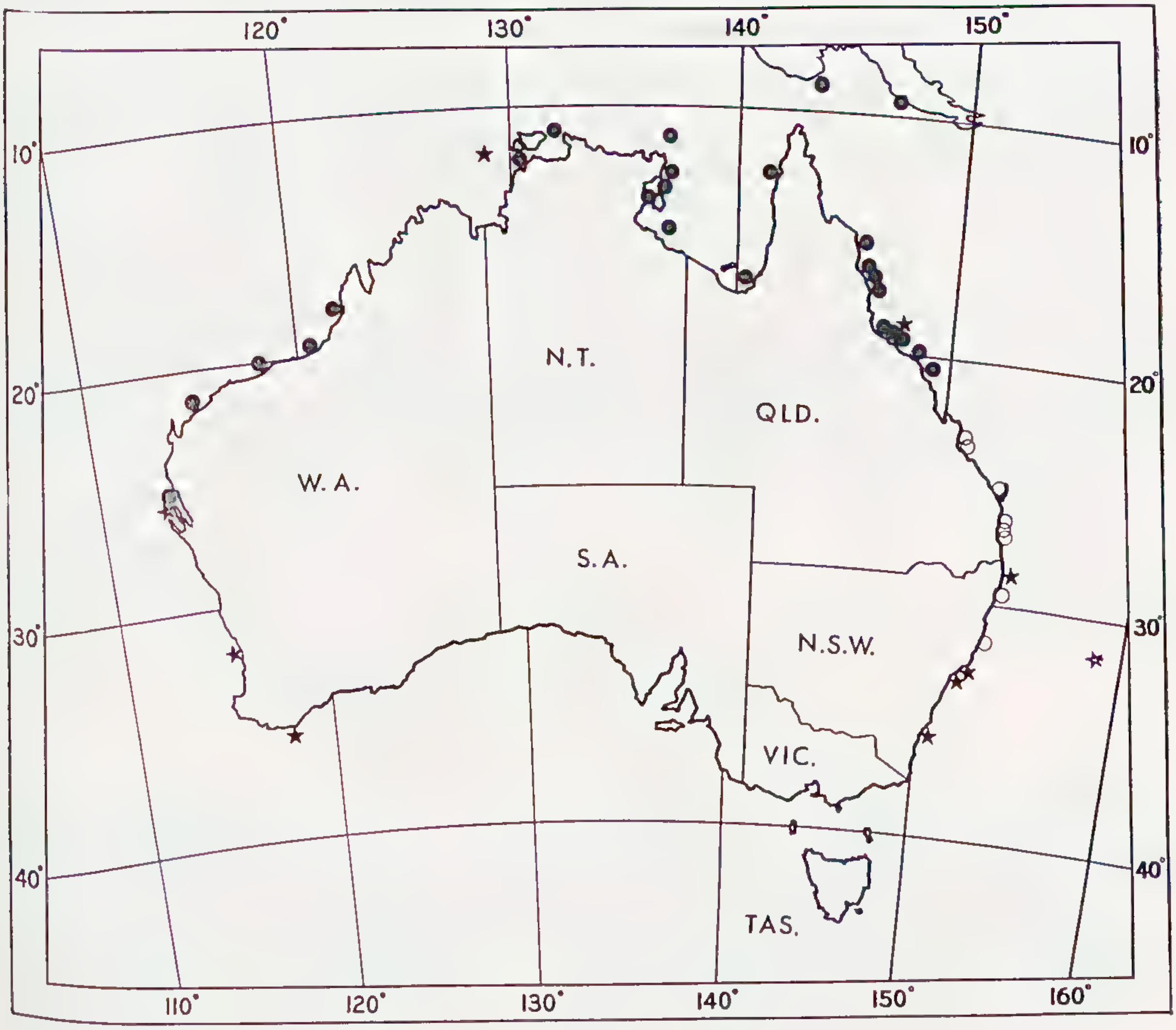


Figure 6. Distribution of *Arrhamphus s. sclerolepis* (dots), *A. s. krefftii* (open circles), and *Euleptorhamphus viridis* (stars) around Australia, based on specimens examined.

The sharp differences between the S. Queensland-New South Wales population on the one hand and the four northern populations on the other in numbers of vertebrae, anal fin rays, gill-rakers, and change in ratio of lower jaw length to head length convince me that there is differentiation on at least the subspecific level.

Distribution

Except for two records from southern New Guinea, *A. sclerolepis* is confined to the northern two-thirds of Australia (Fig. 6). The ranges of the two subspecies are given in the subspecies sections.

The types were originally recorded, as coming from "? New Zealand" by Günther (1866: 277). There is no locality data for either of the types in the original register books and no apparent reason for Günther to have indicated New Zealand as the type-locality. No subsequent specimens have been collected anywhere except Australia (and two individuals from southern New Guinea). Gill (1893: 113) noted that *A. sclerolepis* was wrongly credited to the New Zealand fauna and is a Queensland fish. In his checklist of New Zealand fishes, Whitley (1968a: 36) stated that *Arrhamphus sclerolepis* was Australian. The counts of gill-rakers (23 and 24 on the first arch; 18 and 19 on the second arch) and vertebrae (47) and the head length divided by lower jaw length (13.9 and 11.8) of the types indicate that they probably came from the Northern Territory or Western Australia so the northern population is the nominal subspecies *Arrhamphus sclerolepis sclerolepis* Günther and the southeast subspecies is *A. s. krefftii* (Steindachner).

Material

Listed under the subspecies accounts, 498 specimens (17.9–218 mm SL) from 45 collections of *A. s. sclerolepis* and 72 specimens (17.9–277) from 28 collections of *A. s. krefftii.*

Arrhamphus sclerolepis sclerolepis Günther

Northern Snub-nosed Garfish

Arrhamphus sclerolepis Günther, 1866: 276–7 (original description of genus and species; "? New Zealand" [= Australia]). Hutton, 1872: 54 (description after Günther; doubtful New Zealand species). Macleay, 1878: 364 (Darwin). Klunzinger, 1880: 415 (Port Darwin [SMN 2603] and Port Denison [SMN 2274]; *He. kreftii* Steindachner a synonym of *A. sclerolepis*). Macleay, 1881: 248–9 (in part; Darwin). Sherrin, 1886: 305 (listed, New Zealand). Kent, 1889: 240 (Port Darwin district). Gill, 1893: 113 (*A. sclerolepis* a Qld. species). Rendahl, 1922: 175 (Roebuck Bay, W.A.). Paradice and Whitley, 1927: 80 (Pellew Is. [AMS IA.1486, 1686–7] and Darwin, N.T.). McCulloch, 1929: 104 (in part; N. Qld., N. Australia). Weed, 1933: 54 (description; status of genus). Anon., 1945: 8 (listed as Cairns, Qld. marketable fish). Whitley, 1945: 41 (NW. Australia). Whitley, 1948: 15 (North West Cape to 80 mile Beach and east, W.A.). Roughley, 1951: 23 (in part; W.A.). Fowler, 1957: 66 (Lady Musgrave Island [ANSP 93263], Qld.). Munro, 1957: 55 (in part; description; W.A., N.T., N. Qld.). Taylor, 1964: 103 (description; Arnhem Land [6 USNM collections], N.T.). Whitley, 1964b: 39 (listed). Marshall, 1964: 102–3 (in part; N. Qld., N.T.), colour pl. 6, fig. 112. Marshall, 1966: 112 (common Qld. food fish), colour pl. 6, fig. 112. Collette, 1966: 5 (vertebrae), 6 (pectoral rays), 7 (branchiostegal rays [USNM 173771]). Whitley, 1968a: 36 (*A. sclerolepis* an Australian not New Zealand species). Lake, 1971: 25 (in part).

Diagnosis

Differs from *A. s. krefftii* in having fewer vertebrae and anal fin rays, more gill-rakers on both the first and second arches (Table 1), and in having a proportionately shorter lower jaw at larger sizes. The anal rays are modally 15 in *A. s. sclerolepis*, 16 in *A. s. krefftii*. The vertebrae number 45–48, usually 46 or 47, in *A. s. sclerolepis;* 48–50, usually 49, in *A. s. krefftii*. The gill-rakers on the first arch range from 21–25, usually 23 or 24, in *A. s. sclerolepis* compared to 18–23, usually 19–21, in *A. s. krefftii*. Similarly, the gill-rakers on the second arch range from 16–20, usually 18 or 19, in *A. s. sclerolepis;* 15–18 in *A. s. krefftii*. By adding the number of gill-rakers on the two arches, 96.8% of *A. s. sclerolepis* can be separated from 94.4% of *A. s. krefftii* on a dividing line between 38 and 39 gill-rakers. The lower jaw becomes proportionately much shorter with growth in *A. s. sclerolepis* than in *A. s. krefftii*. The ratio of head length divided by lower jaw length increases from 1.0–2.2 at small sizes (18–50 mm SL) in both subspecies to only 6.0–10.9 in *A. s. sclerolepis* over 270 mm SL compared to 10–20 in *A. s. krefftii* over 140 mm SL (Fig. 4).

Description

Dorsal rays 13–15, usually 14 or 15; anal rays 14–17, usually 15 or 16. Vertebrae (28–31) + (16–19) = 45–48, usually 46 or 47. Gill-rakers on first arch (6–8) + (15–18) = 21–25, usually 23 or 24; on second arch (2–4) + (13–17) = 16–20, usually 18 or 19. Head length divided by lower jaw length increases from 1.0–2.2 at small sizes (18–50 mm SL) to 10–20 at sizes over 140 mm SL (Fig. 4, and see geographic variation). P_2–C divided by P_1–P_2 1.75–2.40, means for the four populations 1.94–2.06. Dorsal base divided by anal base 1.05–1.18, means for the four populations 1.05–1.07.

Maximum known size

218 mm SL (SMN 2274, Port Denison, Qld.).

Types

Arrhamphus sclerolepis Günther. Lectotype; BMNH 1862.11.15.127; Royal College of Surgeons; "? New Zealand" here corrected to Australia (probably Northern Territory or Western Australia); female (118); herein selected because the other syntype is in bad condition. Lower jaw length 2.0 mm; head length 27.7 mm; head length divided by lower jaw 13.85; P_1–P_2 31.1 mm; P_2–C 64.0 mm; P_2–C extension falls well anterior to the tip of the lower jaw; D 14; A 16; P_1 13–13; vertebrae 29 + 18 = 47; RGR_1 7 + 17 = 24; RGR_2 4 + 15 = 19. Preorbital canal without posterior branch (Fig. 1a). Paralectotype BMNH pre-reg.; "old collection;" 1 (191).

Distribution

The northern *A. s. sclerolepis* occurs from Lindeman Island and Bowen, Qld. north to the tip of Queensland, across the top of Australia, and south along the coast of Western Australia to the Gascoyne River (Fig. 6). Two specimens have also been taken in southern New Guinea—Daru area, Dept Agr. Stock Fish. FO–808, 1 (199 mm) and Galley Reach, Manu-Manu, NW. of Port Moresby, DASF FO–2021, 1 (130 mm).

Material

498 specimens (17.9–218 mm SL) from 45 collections arranged from south to north along the east coast of Queensland and then south and west from Cape York.

Queensland, 128 specimens (17.9–218) from 19 collections. AMS IA.6730; Lindeman Is., Cumberland Group; G. P. Whitley; 2 (182–186). SMN 2274; Port Denison; Müller; 3 (179–218). CSIRO; Ticklebelly Bay, Bowling Green Bay; Dec. 7, 1951; 3 (56.2–66.0). CSIRO; Cape Cleveland, Townsville; Dec. 6, 1951; 27 (32.2–64.5). AMS IA.2316–8; Townsville; W. E. J. Paradice; HMAS "Geranium"; Nov. 1924; 3 (139–160). BMNH 1927.2.10.18–20; Townsville; W.E.J. Paradice; HMAS "Geranium", Aug. 1924; 3 (130–155). CSIRO; Paluma Shoals, N of Bluewater Cr., Townsville; Nov. 24, 1941; 20 (34.8–62.6). CSIRO; Rollingstone Cr.; Dec. 11, 1951; 1 (54.5). CSIRO; Flying Fish Point, Innisfail; Feb. 14, 1951; 1 (41.2). AMS IB.1962–3; Cairns; R. le Rossignor; 2 (88.8–91.5). CSIRO; Cairns; Dec. 14, 1951; 35 (17.9–53.1). CSIRO; Port Douglas; Dec. 12, 1951; 2 (26.2–32.4). CSIRO; Port Douglas; Dec. 12, 1951; 15 (37.0–74.2). BMNH 1933.1.25.16; Low Is. off Port Douglas; 1 (154). AMS I.14504; Walkers Bay near Cooktown; A. R. McCulloch; Aug. 1918; 4 (100–106). WAM P–8104–5; Weipa, Gulf of Carpentaria; E. Gamberg; Nov. 1961; 2 (113–114). AMS I.15552–006; SE Gulf of Carpentaria off Norman R., 17° 30′ N, 140° 45′ W; CSIRO; Dec. 15, 1964; 1 (124). USNM 176891; "Great Barrier Reef"; J. Howard; April 8–May 29, 1952; 2 (168–188). ANSP 93263; "Lady Musgrave Is."; Geo. Vanderbilt; 1935; 1 (180).

Northern Territory, 95 specimens (32.0–190) from 17 collections. AMS IA.1486; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice; HMAS "Geranium"; June 1923; 1 (190). AMS IA.1686–7; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice; HMAS "Geranium"; Dec. 1923; 2 (116–163). USNM 173772; Little Lagoon, Umbakumba, Groote Eylandt, Gulf of Carpentaria; R. R. Miller 48–8; April 8–14, 1948; 1 (85.0). USNM 173773; Port Langdon, Groote Eylandt; R. R. Miller 48–10; May 1, 1948; 5 (65.2–105). USNM 173774; S. Bay, Bickerton Is., Gulf of Carpentaria; R. R. Miller 48–13; June 2, 1948; 1 (104). USNM 173776; Port Bradshaw S of Cape Arnhem; R. R. Miller 48–28; July 25, 1948; 23 (85.5–150); and AMS I.16153–002; 10. USNM 173775; Port Bradshaw S of Cape Arnhem; R. R. Miller 48–24; July 26, 1948; 11 (68.8–83.1). CSIRO; Marchinbar Is., Wessel Is.; Oct. 18, 1949; 2 (32.0–43.0). CSIRO C.1716; Port Essington, Cobourg Peninsula; 1 (103). USNM 173771; Nightcliff, 7 mi. N of Darwin; R. R. Miller 48–2; March 19, 1948; 26 (33.5–98.1). AMS I.5308–9; Darwin; Christie and Godfrey; 1902; 2 (153–158). AMS IA.3868; Darwin; L. Wilson; 1 (97.8). AMS IA.7778; Darwin; M. Ward; 1 (84.0). SMN 2603; Port Darwin; 1 (167). SIO 61–58–23A; Darwin; C. Russell and F. Stone; Oct. 17, 1960; 2 (106–110). SIO 61–701–23A; Darwin Bay; Naga Exped. 61–257; April 21, 1961; 2 (89.4–98.7). AMS IA.7804–6; "Northern Territory"; M. Ward; 3 (58.5–67.5).

Western Australia, 273 specimens (37.2–186) from 7 collections. WAM P–174; Broome; W. B. Alexander; 1914; 1 (186). AMNH 40002; Eighty Mile Beach 3 mi. N Wallal Homestead; D. E. Rosen, G. J. Nelson and W. H. Butler; DER 69–77; April 15, 1969; 14 (78.9–110). AMNH 40003; Pretty Pond, inlet outside Port Hedland; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–75; April 13, 1969; 184 (37.2–80.6); USNM 206748, 30; AMS I.16156, 20; and WAM P–20829–48, 20. AMS I.13253; Port Hedland; WA Fish Dept; Aug. 1914; 1 (171). WAM P–2836; Onslow; F. J. Rankin; Jan. 1945; 1 (180). WAM P–7592; Carnarvon Beach; R. M. Walker; Oct. 16, 1960; 1 (158). WAM P–7914; Gascoyne R. at Carnarvon; R. J. McKay; Aug. 28, 1960; 1 (38.8).

"New Zealand" = Australia. BMNH 1862.11.15.127; 1 (118); lectotype of *A. sclerolepis*. BMNH pre-reg.; 1 (191); paralectotype of *A. sclerolepis*.

Arrhamphus sclerolepis krefftii (Steindachner)

Southeastern Snub-nosed Garfish

Hemiramphus kreftii Steindachner, 1867: 332–3 (original description; Port Jackson, N.S.W.; should be spelled *krefftii*), pl. 1, figs 1–2.

Hemirhamphus breviceps Castelnau, 1878: 240 (original description; Brisbane).

Hemirhamphus argenteus.—Castelnau, 1879: 353 (listed), 394 (*breviceps* a synonym of *argenteus;* common at Brisbane, seen only once at Sydney). Macleay, 1881: 246 (after Castelnau, 1879). Tenison-Woods, 1882: 22 (listed), 83 (after Castelnau, 1879). Ramsay, 1883b: 19 (rare in Sydney). Ogilby, 1887: 53 (after Castelnau, 1879; ?young of *He. intermedius?*). Kent, 1893: 298 (beak almost rudimentary), 370 (listed). McCulloch, 1921: 41 (after Castelnau). McCulloch and Whitley, 1925: 139 (after Castelnau). (Not *Hemiramphus argenteus* Bennett, 1840.)

Arramphus sclerolepis Günther, 1880: 33 (Mary R., Qld. [BMNH 1879.5.14.478–483]). Macleay, 1881: 248–9 (in part, Brisbane). Ogilby, 1887: 54 (E. Australia, Port Jackson; *He. Krefftii* Stdr. synonym of *A. sclerolepis*). Kent, 1893: 298 (Moreton Bay, Qld.), 370 (listed). Waite, 1904b: 20 (listed, N.S.W.). Stead, 1906: 68–9 (N.S.W. and Qld., most abundant in lower reaches of Clarence and Richmond R.; ascends into fresh water; reaches 15 inches and 9 oz.; valuable food fish), fig. 26. Stead, 1908: 38–9 (reaches 15 inches and 9 oz.). Ogilby, 1916: 6 (common, Moreton Bay and Brisbane R., Qld.), 49 (listed). Roughley, 1916: 31–2 (N.S.W. and Qld.; estuaries and coastal lakes; description; summer spawner; delicious food fish). McCulloch, 1921: 41 (Richmond and Clarence R. estuaries, N.S.W.), fig. 110a. McCulloch and Whitley, 1925: 138 (previous Qld. records). McCulloch, 1929: 104 (in part; N.S.W., S. Qld.). Roughley, 1951: 23 (in part; northern N.S.W., S. Qld.; moves far upstream; fine food fish). Ogilby, 1954: 9 (after Ogilby, 1916). Bleakly and Grant, 1954: 24 (S. Qld.; enters estuaries and fresh water; description). Munro, 1957: 55 (in part; description; S. Qld., N.S.W.), fig. 392 (after Steindachner, 1867). Marshall *et al.*, 1959: 26 (description, maximum size; Qld.), fig. Grant, 1965: 41 (in part; Qld.; description, habits), fig. Marshall, 1964: 102–3 (in part; description; S. Qld., N.S.W.; valuable food fish; reaches 15 inches), colour pl. 6. Marshall, 1966: 112 (common Qld. food fish), colour pl. 6. Lake, 1971: 25 (in part, southeast slopes, excellent food fish). Williams, 1971: 52 (listed; Brisbane R.). Grant, 1972: 67 (repeat of 1965 ed.).

Hemirhamphus sclerolepis.—Ogilby, 1893: 175–6 (description; northern N.S.W. rivers; New Zealand locality doubtful), pl. 44.

Hemiramphus argenteus.—McCulloch, 1929: 103 (listed, Qld., N.S.W.). Whitley, 1964b: 39 (listed, Australia).

Arrhamphus brevis.—Borodin, 1932: 73 (Brisbane, Qld. [VMM 900]). (Not *Oxyporhampus brevis* Seale, 1909.)

Diagnosis

A. s. krefftii (Table 1) has more anal fin rays (modally 16 instead of 15) and vertebrae (usually 49 vs. 46 or 47), fewer gill-rakers (usually 19–21 on the first arch compared to usually 23 or 24), and a proportionately longer lower jaw at larger sizes (Fig. 4) than *A. s. sclerolepis* as noted in the diagnosis of the nominal subspecies.

Description

Dorsal rays 13–16, usually 14 or 15; anal rays 15–17, usually 16. Vertebrae (30–32) + (17–19) = 48–50 usually 49. Gill-rakers on first arch (5-6) + (13–16) = 18–23; on second arch (2–4) + (11–14) = 15–18, usually 16 or 17. Head length divided by lower jaw length increases from 1.0–2.2 at small sizes (18–50 mm SL) to 6.0–10.9 at sizes over 270 mm SL (Fig. 4, and see geographic variation). P_2–C divided by P_1–P_2 1.62–3.22 ($\bar{x}$ 1.88). Dorsal base divided by anal base 0.93–1.10 ($\bar{x}$ 1.02).

Maximum known size

277 mm SL (female, BMNH unreg., Clarence R., N.S.W.).

Types

Holotype: Hemiramphus krefftii Steindachner. NHMV 5559; Port Jackson, N.S.W.; 1 (240). Lower jaw length 10.8 mm; head length 51.3 mm; head length divided by lower jaw 4.75 (Fig. 4); P_1–P_2 67.9 mm; P_2–C 124 mm; P_2–C extension falls almost on tip of lower jaw; D 15; A 15; P_1 12–12; RGR_1 $6 + 15 = 21$; RGR_2 $3 + 13 = 16$. Preorbital canal without posterior branch (Fig. 1b).

Hemirhamphus breviceps Castelnau. No types extant. Castelnau's description of *He. breviceps* could only be of either *Arrhamphus sclerolepis* or *Hyporhamphus quoyi* because of the very short lower jaw. His description fits comparable sized (120–130 mm SL) *Arrhamphus* much better than *Hy. quoyi.* Total head length in length without caudal: *He. breviceps*—$3\frac{1}{3}$; *Arrhamphus*—3.3–3.6; *Hy. quoyi*—2.4–2.9. Lower jaw extension in length without caudal: *He. breviceps*—12; *Arrhamphus* 11.2–40.9; *Hy. quoyi* 3.3–6.5. Interorbital distance compared to eye diameter: interorbital greater in *He. breviceps* and *Arrhamphus;* orbit greater in *Hy. quoyi.* Pectoral fin length compared to lower jaw length: pectoral longer in *He. breviceps* and *Arrhamphus;* lower jaw longer in *Hy. quoyi.* Pectoral fin compared to total head length: pectoral longer than half total head length in *He. breviceps* and *Arrhamphus;* half total head length greater in *Hy. quoyi.* The other characters given by Castelnau are either the same or similar in both *Arrhamphus* and *Hy. quoyi* or I am not sure enough how Castelnau measured them to be able to make comparisons.

Distribution

A. sclerolepis krefftii occurs from at least Laurieton, N.S.W. (20 mi. S. of Port Macquarie) north to Rockhampton, Qld. (Fig. 6). There are several museum specimens labelled "Port Jackson" but they may have been purchased in the Sydney fish market and so may have been collected in the Clarence and Richmond rivers. There are catch records of "shortbeak garfish" south to Port Jackson, Botany Bay, and St Georges Basin.

Material

72 specimens (17.9–277 mm SL) from 28 collections arranged from south to north.

New South Wales, 45 specimens (133–277) from 15 collections. USNM 206589; Laurieton, 20 mi. of S of Port Macquarie; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1461; March 25, 1970; 9 (199–274). Clarence River, mostly purch. Sydney mkt.: USNM 47774; orig. AMS I.771; 1 (270). USNM 47797; "Port Jackson"; orig. AMS I.730; 1 (252). USNM 59865; D. G. Stead; 5 (133–275). AMS I.772; Aug. 1886; 1 (250). AMS I.7641–3; May 1906; 3 (199–206). AMS I.9519, 9521–3; "near Sydney"; 4 (179–221). AMS I.9855–6; March 1909; 2 (245–267). AMS I.13024–5; May 26, 1905; 2 (263–275). SU 20804; D. G. Stead; 1905; 2 (197–207). AMS I.15217–21; June 1920; 5 (225–269). AMS IA.6545–7; D. G. Stead; May 26, 1905; 3 (262–274). BMNH unreg.; D. G. Stead; April 2, 1912; 2 (243–277). USNM 206571; B. B. Collette and J. R. Paxton; BBC 1376; Dec. 6, 1969; 4 (203–220). NHMV 5559; "Port Jackson", Sydney; 1 (240); holotype of *He. krefftii* Steindachner.

Queensland, 27 specimens (17.9–229) from 13 collections: ANSP 95527; Bellevue Sta., 80 mi. up Brisbane R.; orig. QM I.3581, 3586; 2 (172–216). VMM 900; Brisbane; W. K. Vanderbilt, "Alva"; 1931–32; 1 (229). CSIRO C.2982; Moreton Bay; 1952; 1 (151). CSIRO; Bribie Is. Banks, Caloundra; May 1944; 1 (65.1). CSIRO; N. end Bribie Is.; Jan. 22, 1945; 2 (33.9–42.3). CSIRO; Caloundra; June 14, 1940; 3 (35.0–77.6). CSIRO; Tewantin, Noosa R.; Sept. 24, 1945; 2 (62.5–64.9). CSIRO; Noosa R. above Tewantin; Aug. 31, 1947; 3 (58.5–101). CSIRO; Lake Cooroibah, Noosa R.; Aug. 7, 1944; 1 (68.3). BMNH 1879.5.14.478–483; Mary R.; "Challenger"; 2 (150–195). USNM 206558; Gladstone Harbour; B. B. Collette 1417; Dec. 11, 1969; 7 (17.9–123). AMS unreg.; Fitzroy R.; 1 (214). BMNH 1876.3.29.3; Rockhampton; Godeffroy Mus.; 1 (161).

Euleptorhamphus viridis (van Hasselt)

Fig. 6

Esox maxilla superiore brevi; inferiore longissima, subulata; corpore lineare; squamis variis; cauda biloba. "Kuddera. C" Russell, 1803: 62 (description; Vizagapatan, Coast of Coromandel, India), pl. 178.

Hemiramphus viridis van Hasselt, 1823: 131 (original description based on "Kuddera. C" Russell, 1803, pl. 178).

Hemiramphus longirostris Cuvier, 1829: 286 (original description based on "Kuddera. C" Russell, 1803, pl. 178).

Hemiramphus macrorhyncus Valenciennes *in* Cuvier and Valenciennes 1846: 55–56 (original description; Ellice Is., about 100 mi. E. of Nukufetau Is., formerly Peyster Is., at 180° 7′ S.), fig. 556.

Euleptorhamphus longirostris.—Waite, 1903: 24 (Lord Howe Is. [AMS I.5335], new record). Waite, 1904a: 194 (Lord Howe Is.). Stead, 1907a: 4–6 (Bateman's Bay, N.S.W. [AMS I.15264], new N.S.W. record, description). Stead, 1908: 38 (after Stead, 1907). Waite, 1911: 28 (Kermadec Is., new record). Ogilby, 1916: 6 ("flight" in Wide Bay, Qld.). McCulloch, 1921: 41 (one N.S.W. record), pl. 10, fig. 109a. McCulloch and Whitley, 1925: 138 (Ogilby's 1916 record listed). McCulloch, 1929: 103 (Qld., N.S.W., Lord Howe Is., Kermadec Is.). Whitley, 1943: 177–8 (Bateman's Bay and Tuggerah Entrance, N.S.W. [AMS IB.615); Albany district, W.A. [AMS I.11742]; Noosa R. specimen [AMS IA.7968] with no pelvic fins herein reidentified as *Hy. ardelio*). Whitley, 1948: 15 (W.A., listed). Roughley, 1951: 23–4 (Qld. to W.A., one N.S.W. record). Ogilby, 1954: 10 (after Ogilby, 1916). Munro, 1957: 55 (description; Qld., N.S.W., and W.A.), fig. 390. Whitley, 1964b: 39 (listed). Marshall, 1964: 102 (description; 2 Qld. records—N. of Gladstone and off Lady Elliott Is.), pl. 25, fig. 111. Marshall, 1966: 175, pl. 25, fig. 111. Whitley, 1968a: 36 (Kermadec Is. after Waite, 1911).

Hemiramphus tweediei Herre, 1936: 6–7 (original description; Singapore), pl. 2. Böhlke, 1953: 51 (holotype—SU 30979).

Euleptorhamphus viridis.—Parin, 1964 (description, taxonomy, distribution, geographic variation). Grant, 1972: 62 (col. pl.), 63 (description after Munro, 1957, 1967; known from 4 Qld. specimens that leapt aboard launches; N. of Gladstone, off Lady Elliott Is., and off Southport).

Diagnosis

Euleptorhamphus viridis differs strikingly from all other Australian garfishes in its ribbon-shaped, compressed body, very long pectoral fins, and very long lower jaw. The lower jaw may be as much as half of the standard length. It has more dorsal and anal rays than any other Australian species, 23–25 dorsal and 22–24 anal rays (as few as 21 dorsal and anal rays outside Australian waters) compared to a maximum of 18 dorsal rays (in *Hy. melanochir*) and 20 anal rays (in *Hy. melanochir* and *Hy. australis*). *E. viridis* has fewer pectoral rays than other Australian garfishes, only 8 or 9 compared to 10–14 (rarely 9 in some species of the estuarine genus *Zenarchopterus*). Gill-rakers on the first arch (5–9) + (18–23) = 25–33; gill-rakers on second arch reduced to small bumps that are difficult to count accurately. Vertebral number in *Euleptorhamphus* is much higher than in any other genus of garfishes (69–73 compared to 37–59, Collette, 1966).

Maximum known size

405 mm SL (WAM P–4732, Perth, W.A.).

Types

Both *Hemiramphus viridis* van Hasselt and *Hemiramphus longirostris* Cuvier are based on the figure of "Kuddera. C" in Russell (1803) and no type-specimens are extant.

Hemiramphus macrorhynchus Valenciennes. Type not found but figure in original description shows all the diagnostic characters of *E. viridis*.

Hemiramphus tweediei Herre. Holotype SU 30979; Selat Paoe, Malaya; April, 1923; A.W.C.T. Herre; 1 (180). Lower jaw length 86.0 mm; pectoral fin length 40.9 mm; D 22; A 21; P_1 8–8; RGR_1 $8 + 21 = 29$.

Distribution

An oceanic species found throughout tropical and sub-tropical waters in the Indo-Pacific (Parin, 1964) with only a few scattered Australian records (Fig. 6). It is basically a warm-water species but has been recorded as far south as Bateman's Bay, New South Wales and Albany, Western Australia.

Australian Material

16 specimens (86–405 mm SL) from 15 collections.

New South Wales: AMS I.15264; Bateman's Bay; Jan. 1907; 1 (312). AMS IB.615; ocean beach N of Tuggerah Entrance; P. Clifford; Jan. 1941; 1 (201). USNM 206852; off Newcastle; BBC 1465; April 6, 1970; 1 (250). AMS I.11088 and E. 1664; Byron Bay; "Endeavour"; June 26, 1910; 2 (272–300).

Lord Howe Island: AMS I.5335; F. Farnell; July 1902; 1 (338).

Queensland: AMS IB.5431; Townsville district; G. Coates; 1961; 1 (277).

Western Australia: CSIRO; 12° 02′ S, 128° 59′ E, Timor Sea; "Stanley Fowler"; Oct. 12, 1949; 1 (86.0). WAM P–304; Shark Bay; Fish. Inspector; 1 (365). CSIRO C.2578; Laurieton, Abrolhos Is.; May 1955; 1 (320). WAM P–4732; 2 mi. W. Marmion Beach, N of Perth; P. Richards; Feb. 7, 1960; 1 (405). WAM P–13780; Safety Bay, S of Perth; J. Munro; Dec. 20, 1962; 1 (345). WAM P–5505; Shoalwater Bay S of Perth; Jan. 7, 1963; 1 (390). AMS I.11742; Albany District; A. Abjornsson; June 1911; 1 (288). AMS IB.1959; W. Australia; A. J. Fraser; 1 (360). WAM P–1733; ?W. Australia?; 1 (332).

Hemiramphus far (Forsskål)

Black Barred Garfish

Figs 7, 9

Esox far Forsskål, 1775: 67 (original description; Jidda, Red Sea).

Esox gladius Lacépède, 1803: 295 (original description; Indian Ocean), 308 (pl. 7, fig. 3).

Hemiramphus commersonii Cuvier, 1829: 286 (original description; based on Lacépède, 1803, pl. 7, fig. 3). Alleyne and Macleay, 1877: 349–50 (abundant about Cape York, Qld.).

Hemirhamphus commersoni(i).—Günther, 1880: 50 (Somerset, Cape York, Qld.). Macleay, 1881: 247 (description; Port Jackson, N.S.W. to Cape York, Qld.). Tenison-Woods, 1882: 22 (listed), 83–4 (description; rare in Sydney). Ramsay, 1883a: 29 (rare in N.S.W.). Ramsay, 1883b: 19 (rare in N.S.W.). Munro, 1957: 56 (description; N.S.W., Qld., N.T., and W.A.), fig. 403. Grant, 1965: 40 (description after Munro, 1957; to 20 inches in N. Qld.), fig. Grant, 1972: 66 (description after Munro, 1967; text after Grant, 1965).

Hemiramphus mocquardianus Thominot, 1886: 165–6 (original description; Cambodia).

Hemirhamphus far.—Ogilby, 1887: 54 (range; Port Jackson; reaches 15 inches). Kent, 1893: 298–9 (large species; abundant Thursday Is. and Cooktown, Qld.). Waite, 1904b: 20 (N.S.W.). Stead, 1906: 68 (occasional in N.S.W., fairly common in Qld.). Stead, 1908: 37–8 (fairly common in northern N.S.W.). Cockerell, 1913: 51–2 (description of scales; Qld.). McCulloch, 1921: 41 (northern species common at times in N.S.W.). McCulloch and Whitley, 1925: 139 (previous Qld. records). Paradice and Whitley, 1927: 80 (Darwin and Pellew Is. [AMS IA.1436 and QM I.3968–70]; commonest and largest garfish).

Hemiramphus far.—Weber, 1895: 273 (Thursday Is., Qld.). McCulloch, 1929: 102 (N. Australia, Qld., N.S.W.). Roughley, 1951: 23 (northern N.S.W. to N. Qld.; baitfish). Ogilby, 1954: 10 (N. Qld.), fig. 11. Marshall *et al.*, 1959: 30 (description; Qld.), fig. (from Coates, 1950). Taylor, 1964: 104 (description, in part; Arnhem Land, N.T. [USNM 173777]). Marshall, 1964: 99–100 (description; common on Qld. coast; good food-fish; grows to 20 inches), colour pl. 6, fig. 108. Marshall, 1966: 174 (Qld.), colour pl. 6, fig. 108.

Farhians commersonii.—Whitley, 1930: 250–1 (*Farhians* new genus for *He. commersonii; He. far* (Forsskål) rejected as vernacular). Whitley, 1932a: 276 (synonymy; Low Isles off Port Douglas, Qld. [AMS IA.1676 and BMNH 1933.1.25.15]; description). Whitley, 1948: 15 (listed W.A.). Whitley, 1964b: 39 (listed).

Hemiramphus fer (sic).—Anon., 1945: 8 (listed among Cairns, Qld. marketable fishes). Coates, 1950: 47 (largest of N. Qld. garfishes; prized as baitfish; legal size 9 inches), fig.

Diagnosis

A species of *Hemiramphus* distinguished by its four to six prominent vertical bars on the body (Fig. 7); most other species of the genus lack bars as adults although the other Australian species, *He. robustus*, has the remnants of one bar under the anterior part of the dorsal fin (Fig. 8). Australian specimens of *He. far* differ from most *He. robustus* in having 10 or 11 anal rays instead of 12–14, but a few *He. robustus* have 11 rays and non-Australian specimens of *He. far* sometimes have 12 rays.

Description

Dorsal rays 12–14, usually 13; anal rays 10–11, rarely 12 in Australia; pectoral rays 12–13. Vertebrae (36–37) + 15 = 51–52 in three Australian specimens; (36–38) + (15–16) = 52–54 in a large series of specimens from Port Moresby, New Guinea. Gill-rakers on first arch (6–9) + (19–26) = 25–34, usually 29–31; on second arch (4–7) + (16–21) = 21–27, usually 22–25. Pectoral fin moderate in length; when extended forward, reaches anterior margin of nasal fossa to anterior margin of eye, usually on nasal fossa.

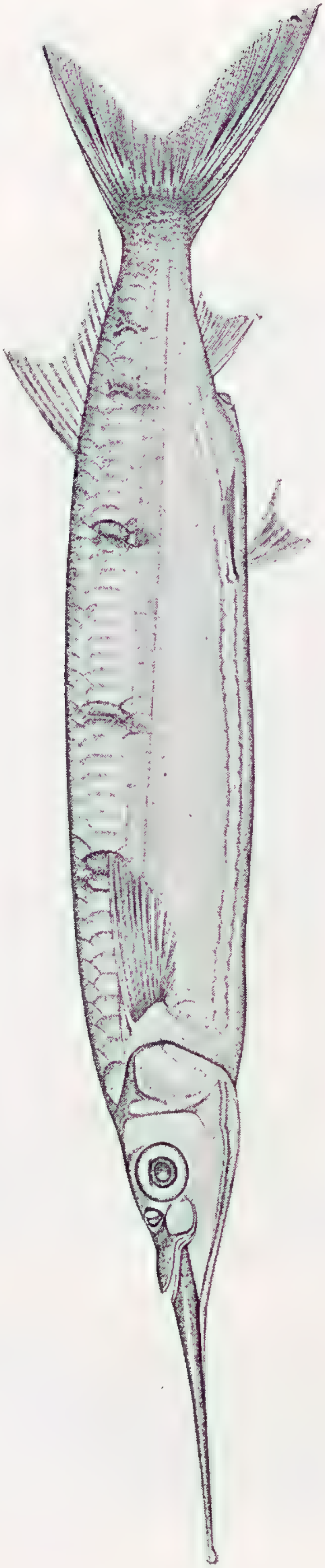


Figure 7. *Hemiramphus far*, USNM 137530, 263 mm SL, Philippine Is.

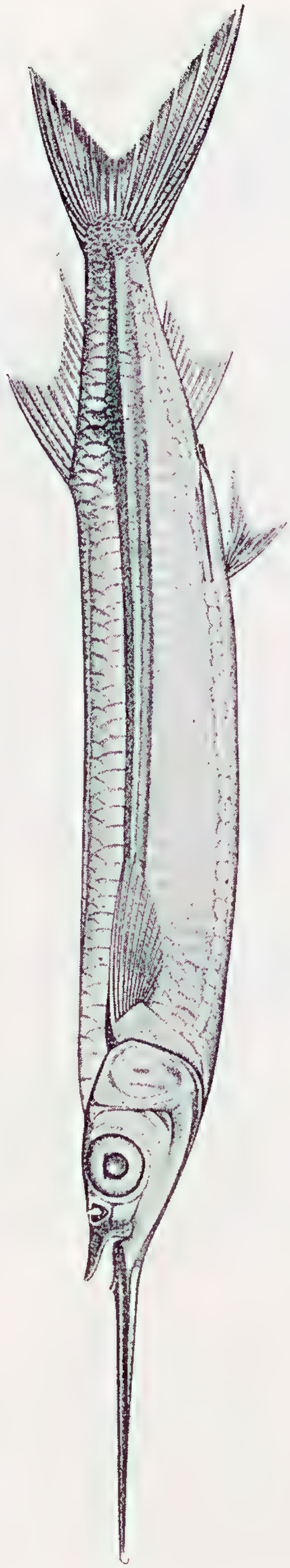


Figure 8. *Hemiramphus robustus*, USNM 206582, 265 mm SL, Perth, W.A.

Maximum known size

270 mm SL in Australia (MNHN A.7639, "Australie"), 317 mm elsewhere.

Types

Esox far, Forsskål, 1775. Type no longer extant according to Klausewitz and Nielsen (1965: 12).

Esox gladius Lacépède, 1803 and *Hemiramphus commersoni* Cuvier, 1829. No types, original description based on the figure in Lacépède (1803, pl. 7, fig. 3) which clearly shows four blotches on the sides of the body.

Hemiramphus mocquardianus Thominot, 1886. Holotype MNHN 86–2; Cambodia; 1 (140). D 12; A 11; P_1 13–12; RGR_1 $9 + 23 = 32$; RGR_2 $6 + 20 = 26$; four prominent body bars.

Discussion

No significant meristic or morphometric differences were found between the Australian population and a large series from Port Moresby, New Guinea. Morphometric characters tested included lower jaw length, pectoral fin length, and body depth.

Distribution

Wide-spread in tropical Indo-West Pacific seas from East Africa and the Red Sea through the Indian Ocean to Australia, the East Indies, and the Philippine Islands. *He. far* has also traversed the Suez Canal to become established in the eastern Mediterranean Sea (Collette, 1965). In Australia, *He. far* is primarily a tropical species known from the Northern Territory and the northern parts of Western Australia and Queensland (Fig. 9). It is more common in the clear waters of the Barrier Reef than in the more turbid coastal waters of eastern Queensland where it is replaced by *He. robustus*. Several authors, starting with Macleay (1881), include New South Wales in the range of *He. far* but I have not seen any specimens south of the Palm Islands and suspect that most southern reports actually refer to *He. robustus*.

Australian Material

29 specimens (33.0–270 mm SL) from 18 collections arranged from south to north and then east to west.

Queensland: QM I.6437–8; Pencil Bay, Palm Is.; 2 (238–251). QM I.6643; Palm Is.; 1 (253). AMS IA.2237–8; Barnard Group, Great Barrier Reef, 17° 40′ S; W. E. J. Paradice, HMAS "Geranium"; Nov. 1924; 2 (228–245). QM I.4077; Barnard Group, Great Barrier Reef, 17° 40′ S; W. E. J. Paradice, HMAS "Geranium"; 1 (212); and ANSP 82296; same data; 1 (216). AMS IA.1676; Low Is., off Port Douglas; W. E. J. Paradice, HMAS "Geranium"; Dec. 1923; 1 (252). BMNH 1933.1.25.15; Low Is.; W. E. J. Paradice; HMAS "Geranium"; Dec. 1923; orig. AMS IA.4480; 1 (238). USNM 176888; Great Barrier Reef; J. Howard; May 29, 1953; 3 (160–187). USNM 176834; Great Barrier Reef; J. Howard May 1953; 1 (241). QM I.1223; Darnley Is., Torres Strait; 1 (248).

Northern Territory: AMS IA.1436; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice, HMAS "Geranium"; June 1923; 1 (204). QM I.3968–70; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice, HMAS "Geranium"; 3 (188–232). USNM 173777; Thompson Bay, Port Langdon, Groote Eylandt, Gulf of Carpentaria; R. R. Miller 48–10; May 1, 1948; 1 (205). AMS IA.7764; Croker Is.; M. Ward; 1 (226). CSIRO; off Black Point, Port Essington, Cobourg Peninsula; Oct. 3, 1949; 1 (33.0). SAM 1140; Palmerston; 1 (195).

Western Australia: WAM P–19108–11; Osborne Is., SE side Admiralty Gulf; R. W. George; Sept. 25, 1967; 4 (151–170). AMS IB.2650; Roebuck Bay; CSIRO; 1 (187).

Australia: MNHN A.7639; Castelnau; 1877–658, 659; 2 (206–270).

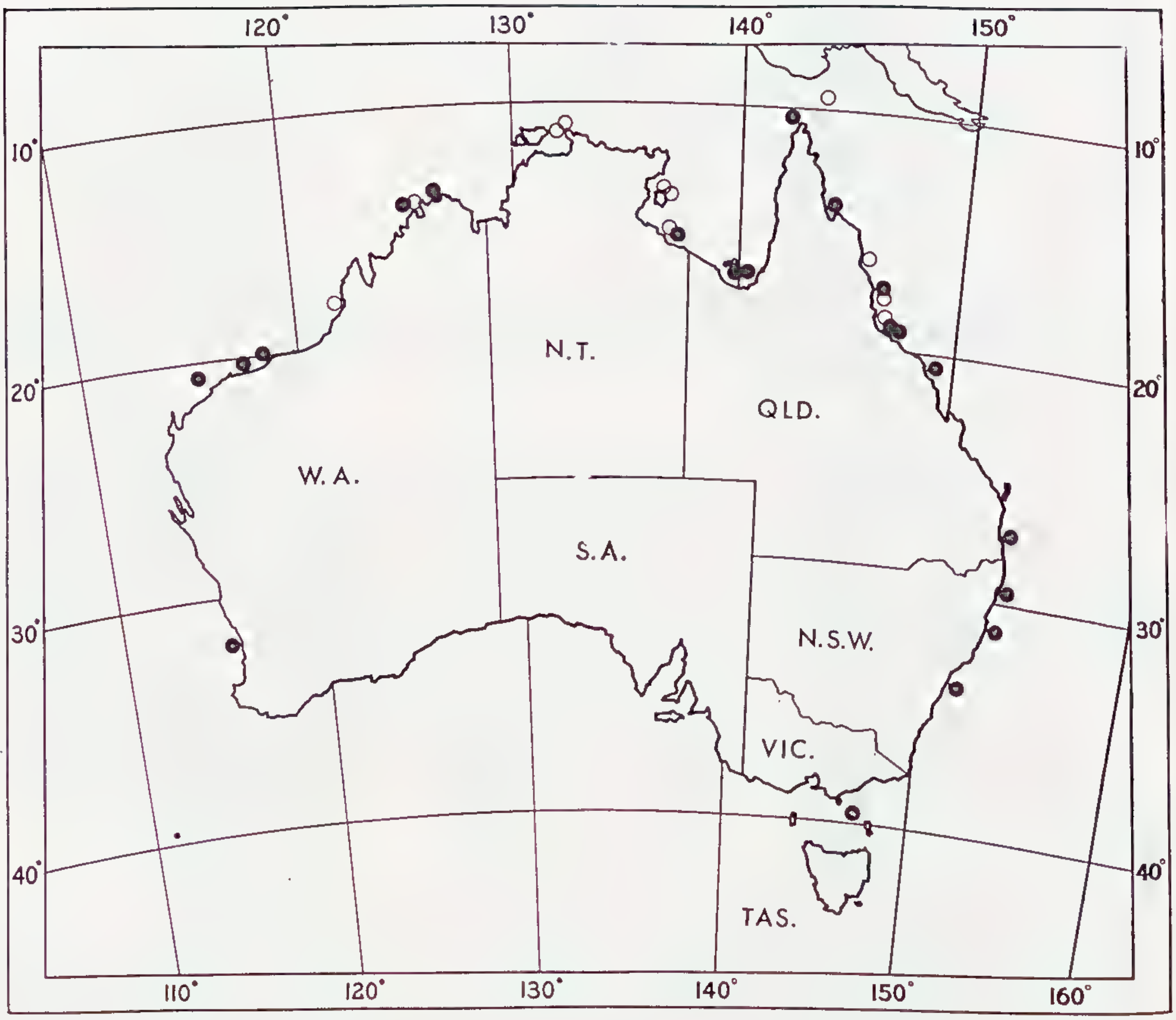


Figure 9. Distribution of two species of *Hemiramphus* (closed circles *He. robustus*, open circles *He. far*) around Australia, based on specimens examined.

Hemiramphus robustus Günther

Three-by-two Garfish

Figs 8–9

Hemirhamphus robustus Günther, 1866: 270–1 (original description; Long Island, Tas.). Munro, 1957: 56 (description after Günther, 1866; "not noticed since original discovery").

Hemirhamphus welsbyi Ogilby, 1908: 91–2 (original description; Moreton Bay, Qld.). McCulloch and Whitley, 1925: 139 (previous Qld. records). Paradice and Whitley, 1927: 80 (Pellew Is. [AMS IA.1678], N.T. and Thursday Is. [AMS IA.1677 and QM I.3974], Qld.; previously known only from types), pl. 11, fig. 2. Böhlke, 1953: 51 (paratypes—SU 20191). Munro, 1957: 56 (description; N.T., Qld., and W.A.), fig. 404 (from Paradice and Whitley, 1927). Grant, 1965: 39 (description after Munro, 1957; well-known in Brisbane markets, most popular garfish for filleting), fig. (from Marshall *et al.*, 1959). Grant, 1972: 65 (repeat of 1965 ed.).

Hemiramphus welsbyi.—McCulloch, 1929: 102 (listed; Qld., N. Australia). Anon., 1945: 8 (listed among Cairns, Qld. marketable fishes). Ogilby, 1954: 9–10 (all along Qld. coast; reaches 16 inches; excellent food-fish; extends further south than *He. far*). Marshall *et al.*, 1959: 31 (description; Qld. coast N. to Torres Strait and N.T.; well-known food-fish), fig. Marshall, 1964: 100 (description; popular food-fish), colour pl. 6, fig. 109. Marshall, 1966: 174 (Qld.), colour pl. 6, fig. 109.

Hemiramphus robustus.—McCulloch, 1929: 103 (listed; Tas.). Whitley, 1964b: 39 (listed).

Ardeapiscis welsbyi.—Whitley, 1931a: 314 (*Ardeapiscis* n. gen. for *He. welsbyi*). Weed, 1933: 56 (characters of genus). Whitley, 1947: 148 (Port Hedland [AMS I.13238] and Fremantle [AMS I.13237, 9], W.A., new state records). Whitley, 1964b: 39 (listed). Whitley, 1968b: 34 (Yamba [AMS IB.7112], N.S.W., new state record).

Ardeapiseis (sic) *welsbyi*.—Whitley, 1948: 15 (W.A. range, listed).

Misidentifications:

Hemiramphus marginatus.—Alleyne and Macleay, 1877: 349 (Palm Is.). Anon., 1945: 8 (listed among Cairns, Qld. marketable fishes). Marshall, 1964: 101 (N. Qld.).

Hemiramphus cantori.—Borodin, 1932: 73 (Brisbane [VMM 898], Qld.).

Farhians commersonii.—Whitley, 1945: 41 (Whitford Beach, Perth [WAM P.2572–3], W.A.).

Hemiramphus far.—Taylor, 1964: 104 (Paradice and Whitley's 1927 records from the Pellew Is. [AMS IA.1677 and QM I.3974], N.T.).

Diagnosis

An endemic Australian species of *Hemiramphus* which differs from *He. far* primarily in having only one dark blotch below the dorsal fin (Fig. 8) instead of 4–6 prominent dark bars on the sides (Fig. 7) and in usually having 12 or 13 anal rays instead of 10 or 11.

Description

Dorsal rays 13–15, usually 13 or 14; anal rays 11–14, usually 12 or 13; pectoral rays 12 or 13, usually 12. Vertebrae (35–37) + (17–19) = 52–55, usually 53 or 54. Gill-rakers on first arch (7–9) + (20–24) = 27–33, usually 29–31; on second arch (3–6) + (16–20) = 20–25, usually 22–25. Pectoral fin moderate in length, extending forward from the middle of the nasal fossa to anterior to the fossa, usually on the anterior margin of the fossa or anterior to the fossa. *He. robustus* does not differ significantly from *He. far* in the length of the pectoral fin or in body depth.

Maximum known size

315 mm SL (WAM P–2572, Perth).

Types

Hemirhamphus robustus Günther, 1866. Holotype BMNH pre-reg; Long Is., Hogan Group, Van Dieman's Land (= Tasmania); J. B. Jukes; female (198). D 14; A 12; P_1 12–12; RGR_1 9 + 22 = 31; RGR_2 5 + 19 = 24; predorsal scales about 34; pectoral fin extended forward reaches to anterior third of nasal fossa; faint trace of blotch on body under first dorsal fin.

Hemirhamphus welsbyi Ogilby, 1908. Holotype QM I.1542; Moreton Bay, Qld; 1 (220). D 13; A 13; P_1 12; RGR_1 8 + 23 = 31; RGR_2 4 + 19 = 23; predorsal scales about 35; pectoral fin extended forward reaches anterior margin of nasal fossa; faint blotch on body under dorsal fin. Paratypes AMS I.12539 (1,213) and SU 20191 (2, 234–252); Moreton Bay.

Discussion

The name *robustus* has apparently not been applied to any specimens following its original use by Günther in 1866. In his Handbook of Australian Fishes, Munro (1957) took its description from Günther. Examination of the types of *robustus* and *welsbyi* leaves no doubt that the two nominal species are conspecific; therefore, the more widely used junior synonym *welsbyi* is replaced by the senior synonym *robustus*.

Australian records of *He. marginatus* are either based on misidentified specimens of *He. robustus* (Alleyne and Macleay, 1877; Anon., 1945; Marshall, 1964) or accounts of *He. marginatus* have been copied from publications on extra-Australian specimens (Munro, 1957).

Distribution

Confined to Australia. Occurs along the northern coast of Australia with *He. far* but extends much farther south, at least to Sydney on the east coast (the type was described from Long Island, Tasmania) and to Perth, Western Australia (Fig. 9). Along the eastern coast of Queensland, *He. robustus* is mostly found in the more inshore turbid waters replacing *He. far* which is more common on the Barrier Reef.

Material

57 specimens (19.3–315 mm SL) from 30 collections.

Tasmania: BMNH pre-reg.; Long Is., Hogan Group, Van Dieman's Land; J. B. Jukes; 1 (198); holotype of *He. robustus*.

New South Wales: AMS I.9670; Port Jackson, Sydney; Macleay Mus.; Dec. 1908; 1 (248). AMS I.15223; Manning R.; D. G. Stead; May 3, 1906; 1 (229). BMNH 1914.8.20.91; Manning R.; D. G. Stead; 1 (200). AMS IB.7112; off Yamba; J. A. Garven; May 1963; 1 (223).

Queensland: QM I.1542; Moreton Bay; 1 (220); holotype of *He. welsbyi*. AMS I.12539; Moreton Bay; 1 (213); paratype of *He. welsbyi*. SU 20191; Moreton Bay; 2 (234–252); paratypes of *He. welsbyi*. QM I.7102; Moreton Bay; Brisbane mkt.; 1 (241). VMM 898; Brisbane; W. K. Vanderbilt, "Alva"; 1931–32; 1 (224). AMS IA.6729; Lindeman Is., Cumberland Group; G. P. Whitley; 1 (163) plus head of another specimen. QM I.5740; Townsville; 1 (182). QM I.6593–4; Townsville; 2 (196–199). QM I.7333; Rattlesnake Is., N. of Townsville; G. Coates; 1 (234). AMS IA.2239–40; Barnard Group, Great Barrier Reef, 17° 40′ S.; W. E. J. Paradice, HMAS "Geranium"; Nov. 1924; 2 (205–210). CSIRO; Little N. Marret R., Princess Charlotte Sound; Sept. 27, 1948; 4 (19.3–29.8). AMS IA.1677; Thursday Is., Torres Strait; W. E. J. Paradice, HMAS "Geranium"; Dec. 1923; 1 (210). QM I.3974; Thursday Is., Torres Strait; W. E. J. Paradice, HMAS "Geranium"; 1 (175). AMS I.15557–048; S.E. Gulf of Carpentaria; 17° 20′ S., 140° 12′ E.; Nov. 23, 1964; CSIRO; "Rama" sta. 1567; 1 (172). AMS IB.6887; Inscription Point, Sweers Is., S. Wellsley Is., Gulf of Carpentaria; D. McMichael and J. Yaldwyn; Dec. 9, 1963; 1 (181).

Northern Territory: AMS IA.1678; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice, HMAS "Geranium"; Dec. 1923; 1 (187).

Western Australia: CSIRO out of C.1751; Mission Bay, Napier Broome Bay; 1 (110). WAM P–19112; Osborne Is., Admiralty Gulf; R. W. George; Sept. 25, 1967; 1 (149). AMS I.13238; Port Hedland; W.A. Fish. Dept; Aug. 1914; 1 (196). AMS IB.2641; Depuch Is.; CSIRO; 1 (190). WAM uncat.; Barrow Is., N. of Onslow; WAM-USNM Exped.; Aug. 25, 1966; 1 (170). WAM P–2572–3; Whitford Beach, Perth; Dec. 1943; 2 (267–315). USNM 206582; Whitford Beach, Perth; purch. Perth mkt.; B. B. Collette, J. R. Paxton, R. J. McKay; BBC–1448; Feb. 13, 1970; 14 (250–295); BMNH 1970.7.28.4–5, 2; AMS unreg., 4. AMS I.13237; Fremantle; W.A. Fish. Dept; Aug. 1914; 1 (260). AMS I.13239; Fremantle; W.A. Fish. Dept; Aug. 1914; 1 (267).

Hyporhamphus regularis (Günther)

River Garfish

Figs 10–13, Tables 3–4

Diagnosis

The river garfish *Hy. regularis* and *Hy. neglectus* are similar to the type-species of *Hyporhamphus*, *Hy. unifasciatus* (Ranzani) and other Atlantic and eastern Pacific species of the genus in having an emarginate caudal fin, lacking a distinct posterior branch to the preorbital canal, and in having the upper jaw distinctly wider than long. All the other Australian species of *Hyporhamphus* have a more deeply forked tail and a distinct posterior branch to the preorbital canal. Among Australian garfishes, *Hy. regularis* is most similar to *Hy. neglectus* but is a larger species (maximum size of 280 vs. 149 mm standard length). *Hy. regularis* has more gill-rakers (Table 3), usually 23 or more on the second arch (compared to usually 23 or less), and usually 31 or more on the first arch (usually 31 or less). The pelvic fins are placed relatively further posteriorly in *Hy. regularis* so that the P_2–C extension usually reaches the orbit instead of anterior to it as in *Hy. neglectus* (Table 3). *Hy. regularis* usually has more vertebrae (Table 3) than *Hy. neglectus* (52 or more vs. 51 or less) except in eastern Queensland where both *Hy. r. ardelio* and *Hy. neglectus* have the same range (51–53) and mean (52.00).

Table 3. Number of fin rays, gill-rakers, and vertebrae, and position of pelvic fins in populations of *Hyporhamphus regularis ardelio*, *Hy. neglectus*, and *Hy. r. regularis* (* indicate types)

Species and Population	Fin Rays													
	Dorsal							Anal						
	13	14	15	16	17	N	$\bar{x}$	14	15	16	17	18	19	N	$\bar{x}$
Hy. r. ardelio															
Victoria..	..	1	5	2	..	8	15.13	..	..	3	5	..	..	8	16.63
New South Wales ..	..	18	62*	5	1	86	14.87	..	..	34	49*	3	..	86	16.65
E. Queensland ..	..	12	21	2	..	35	14.71	..	1	20	14	..	..	35	16.37
Hy. neglectus															
E. Queensland ..	..	4	18	7	..	29	15.10	..	..	14	15	..	..	29	16.52
Gulf of Carpentaria ..	..	6	10	2	..	18	14.78	..	2	9	7	..	..	18	16.28
N. Territory	9	20	11	2	..	42	14.14	9	5	13	14	..	..	41	15.78
W. Australia	..	..	11	2	..	13	15.15	..	..	4	9	..	..	13	16.69
East Indies	..	3	1*	..	..	4	14.25	..	3	1*	..	..	..	4	15.25
Hy. r. regularis	..	6	31*	11	..	48	15.10	..	..	7	38*	2	1	48	16.94

Species and Population	First Arch Gill-rakers													
	25	26	27	28	29	30	31	32	33	34	35	36	N	$\bar{x}$
Hy. r. ardelio														
Victoria..	..	..	..	..	..	1	1	1	3	1	..	..	7	32.29
New South Wales ..	..	..	..	..	..	6	14	22	17	11*	4	1	75	32.39
E. Queensland ..	..	..	..	..	..	2	3	5	5	2	..	..	17	32.12
Hy. neglectus														
E. Queensland ..	..	..	1	1	1	3	4	3	5	..	..	..	18	31.06
Gulf of Carpentaria ..	..	..	..	..	1	1	4	3	1	..	..	..	10	31.20
N. Territory	1	6	5	2	4	4	4	..	..	..	..	..	26	28.15
W. Australia	..	..	..	..	..	2	2	1	2	..	..	..	7	31.43
East Indies	1	1	2*	..	..	..	..	..	..	..	..	..	4	26.25
Hy. r. regularis	..	..	..	..	..	1	7	10*	5	2	..	..	25	32.00

Table 3—*continued*

Species and Population	Second Arch Gill-rakers											
	18	19	20	21	22	23	24	25	26	27	N	$\bar{x}$
Hy. r. ardelio												
Victoria	..	..	..	..	..	..	..	1	3	3	7	26.29
New South Wales	..	..	..	..	1	5	22	22*	21	3	74	24.89
E. Queensland	..	..	..	..	..	4	5	6	2	..	17	24.35
Hy. neglectus												
E. Queensland	..	2	..	3	6	7	..	..	..	..	18	21.89
Gulf of Carpentaria	..	..	..	2	3	3	3	..	..	..	11	22.64
N. Territory	3	8	9	1	3	1	1	..	..	..	26	20.00
W. Australia	..	..	..	2	3	2	..	..	..	..	7	22.00
East Indies	..	..	1	1	2*	..	..	..	..	..	4	21.25
Hy. r. regularis	..	..	..	1	1	8	11*	4	..	..	25	23.64

Species and Population	Gill-rakers on First plus Second Arch																			
	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	N	$\bar{x}$
Hy. r. ardelio	..	..	..	..	..	..	..	..	..	2	7	8	13	9	19	11*	6	3	78	57.17
Hy. neglectus																				
E. Queensland	..	..	1	..	1	1	..	2	1	2	4	2	4	..	..	..	..	..	18	52.94
Gulf of Carpentaria	..	..	..	..	..	..	1	..	1	1	2	..	2	1	..	..	..	..	8	54.00
N. Territory	4	2	3	5	1	2	3	1	1	2	2	..	..	..	..	..	..	..	26	48.15
W. Australia	..	..	..	..	..	..	..	1	1	..	4	1	..	..	..	..	..	..	7	53.43
East Indies	..	1	..	1	..	2*	..	..	..	..	..	..	..	..	..	..	..	..	4	47.50
Hy. r. regularis	..	..	..	..	..	..	..	..	1	1	5	5	5*	3	3	2	..	..	25	55.72

Table 3—*continued*

Species and Population	P₂–C Extension[1]								Total Vertebrae													
	1	2	3	4	5	6	N	$\bar{x}$	47	48	49	50	51	52	53	54	55	56	57	58	N	$\bar{x}$
Hy. r. ardelio																						
Victoria	..	2	3	2	..	..	7	3.0	..	..	..	..	..	..	..	..	3	4	..	..	7	55.57
New South Wales	..	2	3	30	24*	9	68	4.5	..	..	..	..	1	9	24*	15	4	1	..	..	54	53.28
E. Queensland	..	1	5	5	4	5	20	4.4	..	..	..	..	3	5	3	..	..	..	..	..	4	52.00
Hy. neglectus																						
E. Queensland	3	8	3	2	..	..	16	2.3	..	..	..	..	1	5	1	..	..	..	..	..	7	52.00
Gulf of Carpentaria	1	8	3	6	1	..	19	2.9	..	..	..	5	10	..	1	..	..	..	..	..	16	50.81
N. Territory	2	17	4	2	..	..	25	2.2	5	8	3	5	3	..	..	..	..	..	..	..	24	48.71
W. Australia	3	6	1	..	..	..	18	1.8	..	..	1	2	1	..	2	..	..	..	..	..	6	51.00
East Indies	..	1*	2	1	..	..	4	3.0	..	..	..	..	..	..	..	..	..	..	..	..	..	.
Hy. r. regularis	..	6	10*	9	3	1	29	3.4	..	..	..	..	..	1	5	12	3	..	..	1	22	54.00

[1] P_2–C extension coded as follows: 1 = upper jaw; 2 = preorbital; 3 = orbit anterior to pupil; 4 = pupil; 5 = orbit posterior to pupil; 6 = preopercle.

Table 4. Comparison of regression equations and F values for slopes and heights of eight morphometric characters for three Australian taxa of *Hyporhamphus* (= Significant at 99.9% level)**

Character	Regression Equations Y =			F values					
	Hy. r. regularis	*Hy. r. ardelio*	*Hy. neglectus*	*Hy. r. ardelio* vs. *Hy. r. regularis*		*Hy. r. ardelio* vs. *Hy. neglectus*		*Hy. r. regularis* vs. *Hy. neglectus*	
				Slopes	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*
Lower jaw length	0.2002X + 2.608	0.1642X + 6.945	0.0774X + 13.099	9.25	0.502	18.99**	8.51	43.43**	4.33
Head length	0.1285X + 6.985	0.2134X + 0.505	0.2317X − 1.663	90.95**	(65.27)	3.17	1.35	60.82**	11.75
P_1–P_2	0.3459X − 2.299	0.3398X − 0.772	0.3115X + 0.404	0.466	3.67	6.84	22.55**	5.83	3.78
P_1—C	0.4600X − 0.646	0.4597X − 1.154	0.4812X − 0.961	−0.029	1.31	1.98	24.76**	2.72	22.71**
Base dorsal fin	0.1504X − 0.226	0.1478X + 0.347	0.1504X + 0.640	0.257	1.10	0.144	6.13	−0.005	18.68**
Base anal fin	0.1430X + 0.565	0.1384X + 0.590	0.1398X + 1.270	0.576	4.81	0.033	8.83	0.134	1.92
Upper jaw length ..	0.0351X − 0.124	0.0346X − 0.282	0.0411X − 0.832	0.044	5.02	2.55	1.23	2.33	0.670
Upper jaw width ..	0.0558X − 0.861	0.0547X − 0.529	0.0493X − 0.281	0.153	2.07	0.932	4.94	3.03	1.31
Degrees of freedom ..				1, 74–79		1, 68–83		1, 46–56	

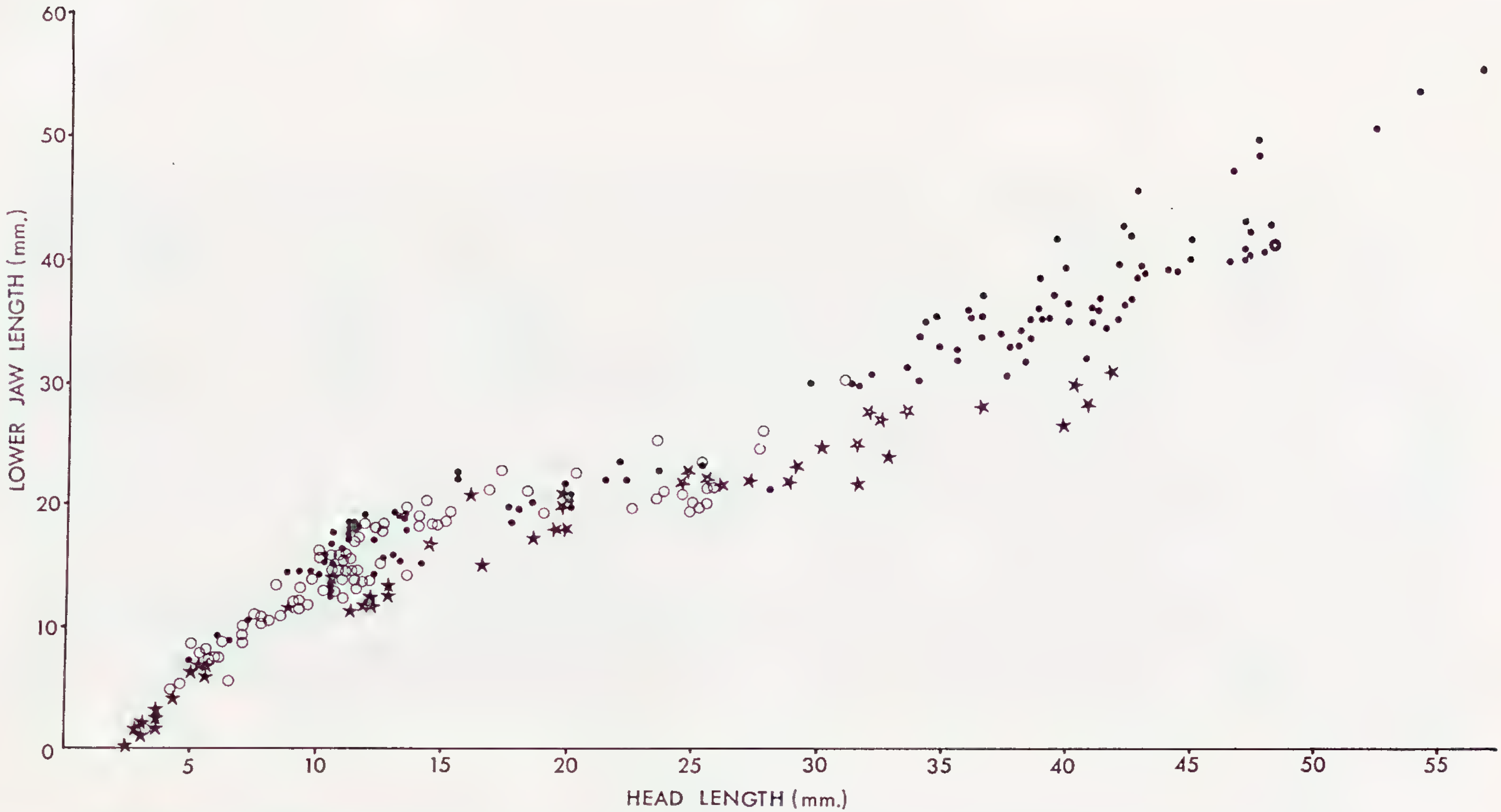


Figure 10. Relationship of lower jaw length to head length in two Australian species of *Hyporhamphus* (stars = *Hy. r. regularis*; dots = *Hy. r. ardelio*, large dot = lectotype; open circles = *Hy. neglectus*).

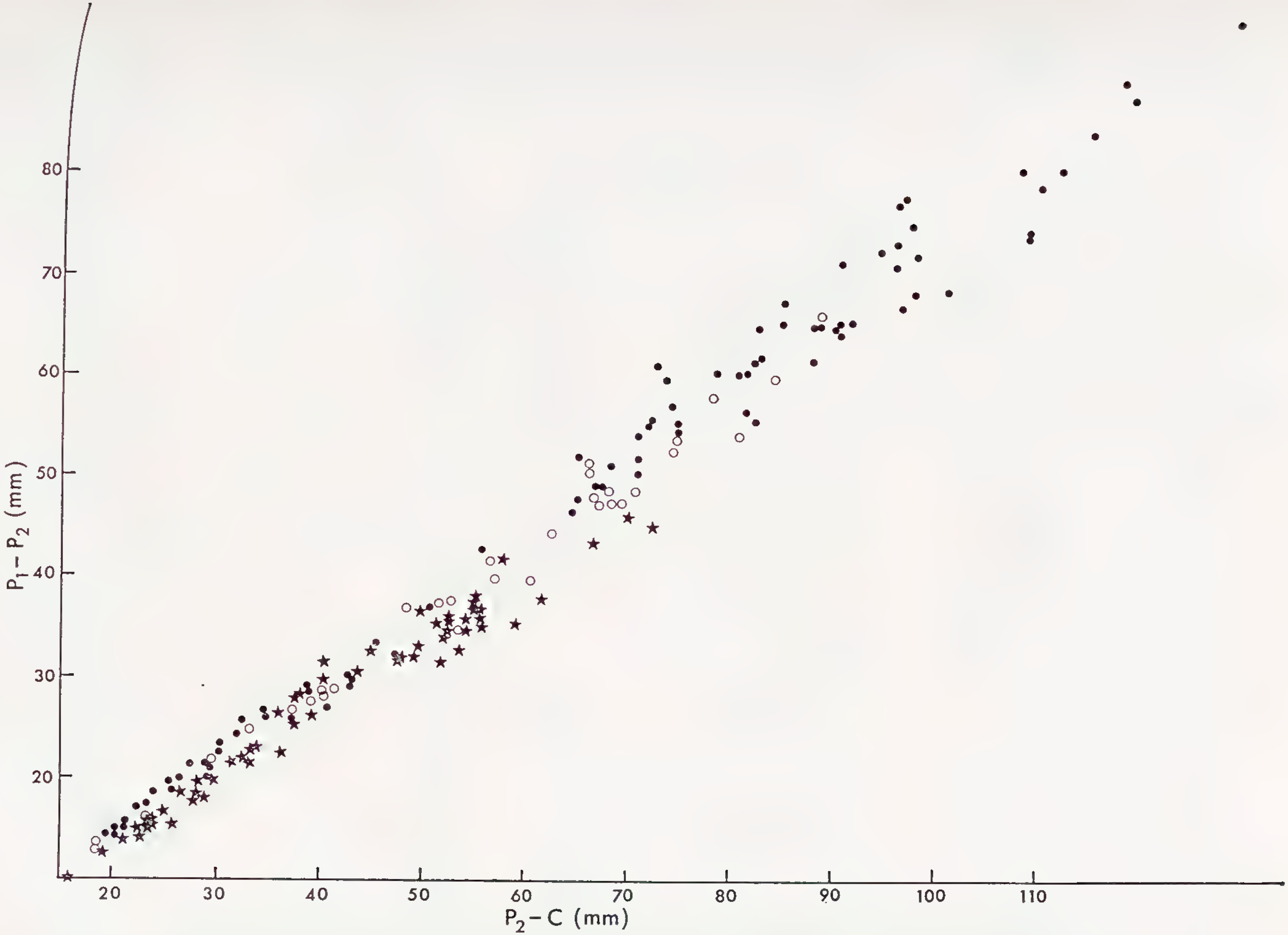


Figure 11. Relationship of pectoral to pelvic distance (P_1–P_2) with pelvic to caudal base distance (P_2–C) in two Australian species of *Hyporhamphus*. Open circles = *Hy. r. regularis;* dots = *Hy. r ardelio;* and stars = *Hv. neglectus.*

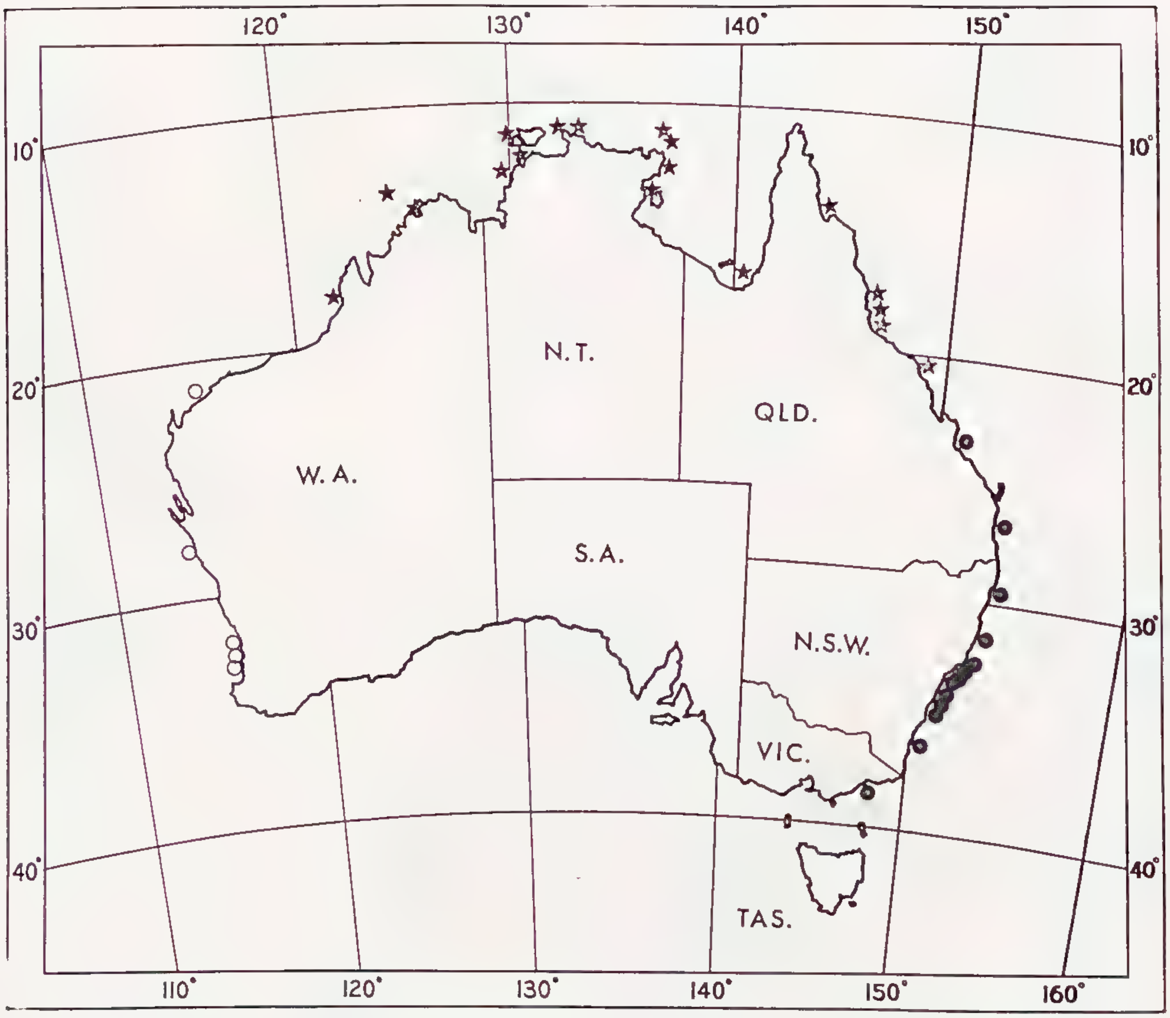


Figure 12. Distribution of two species of *Hyporhamphus* (open circles = *Hy. r. regularis;* dots = *Hy. r. ardelio*; stars = *Hy. neglectus*) around Australia, based on specimens examined.

Description

Posterior branch of preorbital canal absent (Fig. 1, g–j). Lower jaw length moderate, usually shorter than head length (Fig. 10); head length divided by lower jaw length 0.67–1.29. Pelvic fins inserted far forward; P_2–C much greater than P_1–P_2 (Fig. 11); P_2–C divided by P_1–P_2 1.2–1.5, $\bar{x}$ 1.4; P_2–C extension falls on preorbital to preopercle, usually on orbit (Table 3). Dorsal rays 14–17, usually 15; anal rays 15–19, usually 16 or 17; pectoral rays 11 or 12. Vertebrae (33–38) + (18–20) = 51–58. Gill-rakers on first arch (9–12) + (20–25) = 30–36, usually 31–34; on second arch (3–6) + (17–22) = 21–27. Total gill-rakers on first plus second arches 52–61, usually 54–59. Upper jaw broadly rounded, much shorter than wide; width divided by length 1.1–1.9. Bases of dorsal and anal fins about equal in length; dorsal base divided by anal base 0.95–1.15. Maximum body depth much greater than width.

Discussion

The eastern and western populations of *Hy. regularis* have been considered as species since Whitley (1931a) described *Hy. ardelio*. However, the populations show little meristic differences (Table 3) and the regression of head length on standard length was the only one of eight morphometric characters tested where *Hy. r. regularis* was significantly different from *Hy. r. ardelio* (Table 4). Thus, the populations are plainly not different species but I have decided to recognize them as subspecies because the populations are isolated at present and have been considered different in the recent literature.

Distribution

Hy. regularis is divided into two populations, one on the southeast coast of Australia and one on the southwest coast (Fig. 12).

Material

Listed under the subspecies accounts, 78 specimens (12.8–195 mm SL) from 11 collections of *Hy. r. regularis* and 193 specimens (18.1–280 mm SL) from 54 collections of *Hy. r. ardelio.*

Hyporhamphus regularis regularis (Günther)

Western River Garfish

Figs 10–12, Tables 3–4

Hemirhamphus regularis Günther, 1866: 261–2 (original description; Australia and West Australia). Stead, 1906: 67–8 (in part, W.A.; description). Roughley, 1916: 29–31 (in part, W.A.). Munro, 1957: 56 (W.A., description).

Hyporhamphus regularis.—McCulloch, 1929: 102 (listed, in part, W.A.). Roughley, 1951: 21–2 (description, in part, W.A.).

Reporhamphus regularis.—Whitley, 1931a: 314 (*He. regularis* Günther restricted to W.A.; N.S.W. population described as *R. ardelio* new species; both species placed in *Reporhamphus* new genus). Weed, 1933: 59 (in discussion of *Reporhamphus*).

Tortonese, 1939: 256–7 (discussion of validity of *Reporhamphus*). Whitley, 1948: 15 (listed, W.A.). Fraser, 1953: 9 (included in list of estuarine fisheries of minor importance, W.A.). Whitley, 1957: 21 (comparison with *R. ardelio;* reaches 16¼ inches and about 1 lb., W.A.). Whitley, 1960: 45 (W.A., related to *R. ardelio*). Whitley, 1964b: 38 (listed).

Diagnosis

Hy. r. regularis is a smaller subspecies (maximum length 195 mm SL versus 280 mm) and differs from *Hy. r. ardelio* in having a relatively shorter lower jaw compared to head length, especially at larger sizes (Fig. 10).

Description

Head length divided by lower jaw length 0.67–1.19, $\bar{x}$ 0.85. Anal rays 16–19, usually 17. Vertebrae (34–38) + (18–20) = 52–58, usually 53 or 54. Gill-rakers on first arch (9–10) + (21–24) = 30–34, usually 31–33, on second arch (4–6) + (17–21) = 21–25, usually 23 or 24; total gill-rakers on first plus second arches 52–59, usually 54–56. Upper jaw broadly rounded, much shorter than wide; width divided by length 1.11–1.69, $\bar{x}$ 1.44.

Maximum known size:

Female, 195 mm SL (AMS I.13252, Swan R., Perth, W.A.).

Lectotype

BMNH 1843.5.19.91, male, 151 mm SL, essentially selected by Whitley (1931a: 314) who restricted *Hy. regularis* to Western Australia because Günther gave only "Australia" for the other specimens in the type-series. D 15; A 17; P_1 11–11; RGR_1 10 + 22 = 32; RGR_2 5 + 19 = 24; P_1–P_2 49.0 mm; P_2–C 70.0 mm; P_2–C extension falls on orbit anterior to pupil; preorbital canal without posterior branch (Fig. 11). Paralectotypes BMNH 1847.7.21.77–81, Australia, 8 (133–180).

Distribution

A Western Australian endemic, found from the mouth of the Murchison River south to Leschanault Estuary, Bunbury (Fig. 12). There is one questionable record (AMS IB.1586) from much further north—Onslow. Most specimens are from around Perth, particularly in the Swan and Canning rivers.

Material

78 specimens (12.8–195 mm SL) from 11 collections arranged from north to south along the coast of Western Australia. ?AMS IB.1586; Onslow; CSIRO; 1 (142). WAM P–19107; Murchison R. mouth; I. Elliott; April 1965; 1 (146). WAM P–16731–2; Tutula Well, Murchison R.; R. J. McKay; Jan. 23, 1969; 2 (125–129). USNM 206561; Canning R., Perth; B. B. Collette, J. R. Paxton, R. J. McKay; BBC 1449; Feb. 13, 1970; 1 (158). AMS I.13247–52; Swan R., Perth; W.A. Fish. Dept; Aug. 1914; 6 (139–195). CSIRO; Swan R., Perth; April 12, 1941; 3 (85.8–88.8). WAM P–146; Swan R., Perth; W.A. Fish Inspector; 2 (174–180). WAM P–8937–42; Canning R., Rossmoyne, Perth; R. J. McKay; Dec. 7, 1964; 6 (109–143). WAM P–6121–28; Murray R., south of Perth; M. Graham; March 10, 1963; 8 (47.0–147). USNM 206568; Leschanault Estuary at Koombana Caravan Park, Bunbury; B. B. and S. E. Collette and J. R. Paxton; BBC 1437; Feb. 13, 1970; 47 (12.8–100). BMNH 1843.5.19.91; W. Australia; 1 (151); lectotype of *He. regularis*; purch. from Turner.

Hyporhamphus regularis ardelio (Whitley)

Eastern River Garfish

Figs 10–13, Tables 3–4

Hemiramphus Gaimardi Valenciennes *in* Cuvier and Valenciennes, 1846: 36–7 (in part, two syntypes from Sydney [MNHN 4590–1], other syntypes are *Hy. quoyi*). Kner, 1887: 323 (in part, specimens [NHMV uncat.] from Sydney).

Hemirhamphus regularis Günther, 1866: 261–2 (original description, in part, specimens from "Australia"). Castelnau, 1879: 355, 360, 394 (common garfish of Sydney market [MNHN A.4068]; description). Macleay, 1881: 245–6 (description; Port Jackson). Tenison-Woods, 1882: 22 (listed), 83–4 (description; favorite breakfast food in Sydney), plate 37 (lower fig.). Ramsay, 1883a: 28–9 (N.S.W.; food value). Ramsay, 1883b: 4, 19 (N.S.W.; river garfish; food value), 26 (canned), 45 (listed). Ogilby, 1887: 53 (common, Port Jackson; good table fish). Cohen, 1892: 17 (comparison with sea garfish; spawning habits). Kent, 1893: 370 (Qld., listed). Ogilby, 1893: 174–5 (long description; colour; spawning habits; food value; abundant N.S.W. south to Illawarra). Waite, 1904b: 20 (N.S.W., listed). Stead, 1906: 67–8 (in part, N.S.W., S. Qld., and Vict. coastal lakes and estuaries; 5,000 70–80 lb. baskets per year landed in N.S.W.). Stead, 1907b: 33–4, fig. 9 (eggs). Stead, 1908: 37 (one of principle N.S.W. market fishes), pl. 11 (photo). Stead, 1910: pl. 2, no. 4 (photo of river garfish—common N.S.W. food fish). Roughley, 1916: 29–31 (in part, N.S.W. and S. Qld.; description; food fish), colour pl. 5. McCulloch, 1921: 41 (abounds in N.S.W. coastal lakes, harbours, and estuaries; a prime market species; reaches 14 inches). McCulloch and Whitley, 1925: 138 (previous Qld. records). Lewis and Ellway, 1971: 62 (Tallebudgera Cr., S. Qld.).

Hemiramphus regularis.—McCoy, 1887: 134 (Gippsland Lakes, Vict.; compared with sea garfish). Marshall *et al.*, 1959: 29 (description; Qld.), fig. (after Stead). Marshall, 1964: 100 (common in S. Qld. but not as abundant as in N.S.W.).

Hyporhamphus regularis.—McCulloch, 1929: 102 (in part, N.S.W. and Qld.). Fowler, 1940: 757 (Sydney [USNM 83047], Wilkes Exped. 1838–42). Mack, 1941: 104 (Gippsland Lakes, Vict.; catch rate 0 to 300,000 lbs per year, 1911–1937; 0–30% by volume, of food of large black comorant). Roughley, 1951: 21–2 (in part; most abundant in N.S.W.; important constituent of fishery, 200,000 lbs landed in 1948–9), colour pl. 4. Fowler, 1953: 12–13 (description; behaviour; Wilkes Exped. specimens—see Fowler, 1940).

Reporhamphus ardelio Whitley, 1931a: 314 (original description, Clarence R., N.S.W.; considered specifically distinct from the W.A. river garfish *He. regularis* Günther; placed in new genus *Reporhamphus* Whitley). Weed, 1933: 59 (in discussion of *Reporhamphus*). Tortonese, 1939: 256–7 (in discussion of *Reporhamphus*). Whitley, 1956: 40 (listed as freshwater species). Whitley, 1957: 20–1 (Qld., N.S.W., Vict.; enters freshwater; description; comparison with *R. regularis*), fig. Whitley, 1959b: 310, 314 (lectotype AMS I.12744), fig. of lectotype. Whitley, 1960: 44–5 (description; habits; Qld., N.S.W., and Vict.). Whitley, 1964b: 38 (listed).

Hemirhamphus ardelio.—Munro, 1957: 56 (description; Qld. and N.S.W.), fig. 398 (after Stead). Thomson, 1959a: 356 (important part of catch in some years in Lake Macquarie, N.S.W.), 357 (fig. 3, catch composition 1941–56), 359 (fig. 5, catch curve—200–500 lbs per man), 360 (fig. 6, catch curve 3,000 to 19,000 lbs

per year). Thomson, 1959b: 366 (Lake Macquarie, N.S.W.), 369 (herbivore, *Zostera* in 80% of stomachs). Lake, 1959: 3 (saltwater fish occasionally entering freshwater, N.S.W.). Grant, 1965: 36 (description after Munro, 1957; panfish and baitfish; Qld.), fig. Grant, 1972: 60 (repeat of 1965 ed.).

Misidentifications:

Euleptorhamphus longirostris.—Whitley, 1943: 177–8 (Noosa R., Qld. specimen [AMS IA.7968] with no pelvic fins). Whitley, 1961: 299 (same specimen as in Whitley, 1943).

Reporhamphus australis.—Whitley, 1961: 301 (Port Stephens, N.S.W. specimen [AMS IB.779] with 3-pronged beak; Port Macquarie, N.S.W. specimen [AMS IB.780] with deformed mouth), 300 (photo of first specimen).

Diagnosis

A subspecies of *Hyporhamphus regularis* similar to but larger than the Western Australian *Hy. r. regularis*. Differs from *Hy. r. regularis* in having a slightly longer lower jaw, particularly at larger sizes (Fig. 10).

Description

Head length divided by lower jaw length 0.63–1.29, $\bar{x}$ 0.99. Anal rays 15–18, usually 16 or 17. Vertebrae (33–36) + (18–20) = 51–56, usually 52–54. Gill-rakers on first gill arch (9–12) + (20–25) = 30–36, usually 31–34; on second arch (3–6) + (18–22) = 22–27, usually 24–26. Upper jaw broadly rounded, wider than long; width divided by length 1.2–1.9, $\bar{x}$ 1.56.

Maximum known size

Female, 280 mm SL (USNM 206577, Eden, N.S.W.).

Types

Lectotype AMS I.12744, Iluka near mouth of Clarence River, N.S.W.; purch. Sydney mkt.; March 1913; female, 217 mm SL; selected and figured by Whitley (1959b: 310). Lower jaw length 41.8 mm; head length 48.4 mm; P_1–P_2 77.5 mm; P_2–C 96.6 mm; P_2–C extension falls on posterior part of eye; D 15; A 17; P_1 11–12; RGR_1 10 + 24 = 34; RGR_2 5 + 20 = 25; vertebrae 35 + 18 = 53; no posterior branch on preorbital canal (Fig. 1g). Paralectotypes AMS I.12745–6; same data as lectotype; 2 females (140–192).

Distribution

An east Australian endemic, found from Gladstone, Qld. south in coastal rivers and estuaries to Lakes Entrance, Vic. (Fig. 12).

Material

193 specimens (18.1–280 mm SL) from 54 collections arranged from north to south along the coast.

Queensland: 35 specimens (29.0–171) from 9 collections. USNM 206545; Gladstone Harbour; B. B. Collette 1417; Dec. 11, 1969; 4 (29.0–103). CSIRO; The Bluff, S. Fraser I.; Aug. 24, 1950; 18 (43.9–69.8). CSIRO; Rocky Point, Mary R.; Sept. 2, 1950; 1 (88.3). CSIRO; Noosa R.; Feb. 21, 1947; 1 (46.7). AM IA.7986; Noosa R.; T. Iredale; 1 (51.5). CSIRO; Caloundra; Nov. 12, 1944; 5 (75.1–90.2). CSIRO; Caloundra; June 14, 1940; 1 (88.3). AMS A.12490–1; "Queensland"; Spalding; 1882; 2 (150–168). SU 20561; Brisbane R.; J. D. Ogilby; 2 (169–171).

Figure 13. *Hyporhamphus regularis ardelio*, USNM 206573, 186 mm SL, Laurieton, N.S.W.

New South Wales: 150 specimens (18.1–280) from 43 collections. USNM 176983; New South Wales; J. Howard; Feb. 2–March 11, 1953; 8 (189–216). AMS I.12744 (lectotype), 12745–6 (paralectotypes); Iluka, Clarence R.; Sydney mkt.; March 1913; 3 (140–217). CSIRO; Yamba Bay, Clarence R.; May 20, 1946; 1 (44.6). CSIRO; Clarence R. between Maclean and Harwood Is.; April 19, 1948; 1 (18.1). AMS IB.780; Port Macquarie; 1 (200). USNM 206573; Laurieton; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1461; March 25, 1970; 13 (158–215). AMS I.14943–5; outside Port Stephens Heads; D. G. Stead; 3 (148–162). AMS IB.779; Port Stephens; 1 (115). USNM 148614; off Newcastle; H. J. Brown; 1909; 1 (131). USNM 206578; Mannering Park, Lake Macquarie; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1376; Nov. 6, 1969; 3 (177–228). CSIRO C.3123; North Creek, Lake Macquarie; Sept. 12, 1956; 7 (127–145). CSIRO; Marks Point, Lake Macquarie; Sept. 25, 1956; 8 (43.8–59.6). CSIRO; The Islands, Lake Macquarie; Aug. 15, 1956; 1 (49.7). CSIRO A.2081–2; Lake Macquarie; 1953; 2 (40.9–48.1). USNM 59912; Tuggerah Lake; D. G. Stead; 5 (156–224). SU 20780; Tuggerah Lake; D. G. Stead; 1906; 3 (157–167). CSIRO; Tuggerah Lake; Jan. 3, 1940; 1 (60.0). AMS IB.1412; Toukley, near Wyong on Tuggerah Lake; W. Barnes; March 1945; 1 (47.2). USNM 206572; Tuggerah and Macquarie Lakes; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1455; March 5, 1970; 8 (169–195). USNM 206563; Jerusalem Bay on Broken Bay; R. B. Talbot; BBC 1423; Jan. 1, 1970; 2 (25.0–33.3). MNHN 4590–1; Port Jackson; Sydney; Quoy and Gaimard, Urville Exped.; 2 (177–179). SU 8318; Sydney; D. H. Campbell; 1 (154). MNHN A.4068; Sydney; Castelnau; 1879; 2 (168–178). NHMV 5571; Port Jackson; Steindachner; 1884; 2 (155–172). NHMV; Sydney; "Novara" Exped.; 1857–9; 3 (150–167). BMNH 1890.9.23.242–3; Port Jackson; Imperial Institute; 2 (168–172). USNM 83047; Sydney; Wilkes Exped.; 2 (91–185). IRSNB 1228B; Port Jackson; exchange from Sydney Mus., 1882; 5 (152–165). AMS I.7637, 7639–40; Port Jackson; N.S.W. Fish. Comm.; May 1906; 3 (143–226). USNM 47792; Port Jackson; orig. AMS A.9914; 3 (162–169). ZMH 1771; Watson's Bay, Sydney; P. Timm; April 20–May 17, 1914; 2 (174–181). AMS I.9527–29, 9531; near Sydney; N.S.W. Fish. Dept; Sept. 1908; 4 (152–163). AMS I.4448; Sydney mkt.; July 1900; 1 (220). AMS old coll.; no data—prob. near Sydney; 2 (162–211). USNM 206576; N. and S. of Sydney; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1370; Sept. 18, 1969; 12 (170–200). CSIRO C.2126–9; Lake Illawarra; 1953; 4 (163–165). BMNH 1914.8.20.85–90; Lake Illawarra; July 11, 1911; D. G. Stead; 6 (160–165). AMS I.15222; Lake Illawarra; D. G. Stead; June 21, 1909; 1 (260). USNM 206574; Nowra; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1463; April 3, 1970; 6 (179–200). USNM 206570; Sussex Inlet; W. Ivantsoff; Jan. 25, 1970; 4 (64.4–168). CSIRO; Lake Conjola; July 11, 1948; 3 (87.3–94.0). CSIRO; Narooma; Aug. 21, 1941; 4 (102–125). USNM 206577; Eden; Sydney mkt.; B. B. Collette 1472; May 1, 1970; 3 (184–280).

Victoria: USNM 206588; Lakes Entrance; Sydney mkt.; B. B. Collette 1469; April 17, 1970; 7 (194–271). CSIRO; North Arm, Lakes Entrance; Dec. 1, 1939; 1 (32.6).

Hyporhamphus neglectus (Bleeker)

Figs 10–12, 14, Tables 3–4

Hemirhamphus neglectus Bleeker, 1866: 157–8 (original description; Indonesia).

Hyporhamphus gaimardi.—Taylor, 1964: 104–5 (Arnhem Land, N.T. [4 USNM coll.]; description). (Not *Hemiramphus gaimardi* Valenciennes, 1846.)

Diagnosis

A small (maximum size in Australia 149 mm SL) northern species of *Hyporhamphus* distinguished from *Hy. regularis* by the lower number of gill-rakers, usually 23 or fewer on the second arch and 31 or fewer on the first arch (compared to 24 or more and more than 31). Pelvic fins placed relatively further anterior so that the P_2–C extension usually falls anterior to the orbit instead of on it as in *Hy. regularis*. *Hy. neglectus* has fewer vertebrae (usually 51 or less) than *Hy. regularis* (usually 52 or more) except in eastern Queensland where both *Hy. r. ardelio* and *Hy. neglectus* have the same range (51–53) and mean (52.00).

Description

Posterior branch of preorbital canal absent (Fig. 1, k–m). Lower jaw length moderate, slightly shorter than head length in adults, longer in juveniles (Fig. 10); head length divided by lower jaw length 0.63–1.26, $\bar{x}$ 0.95. Pelvic fins inserted far forward; P_2–C much greater than P_1–P_2 (Fig. 11); P_2–C divided by P_1–P_2 1.35–1.68, $\bar{x}$ 1.49; P_2–C extension falls on base of upper jaw to orbit, usually on orbit. Dorsal rays 13–16, usually 14 or 15 (Table 3); anal rays 14–17, usually 16 or 17; pectoral rays 10–12, usually 11. Vertebrae (31–35) + (16–19) = 47–53. Gill-rakers on first arch (7–11) + (17–24) = 25–33, usually 31 or less; on second arch (2–5) + (15–19) = 18–24, usually 19–23; total of gill-rakers on first plus second arches 44–57, usually 54 or less. Dorsal fin base length equal to or greater than length of anal fin base (dorsal base divided by anal 0.92–1.17, $\bar{x}$ 1.03). Upper jaw wider than long (width divided by length 1.15–1.67, $\bar{x}$ 1.43). Maximum body depth much greater than maximum body width.

Maximum known size

Female, 149 mm SL (AMS IA.2315, Townsville, Qld.). Males mature, with well-developed testes at 104–137 mm SL; females with large eggs at 102–149 mm SL.

Types

Lectotype BMNH 1866.5.2.18; East Indies; Bleeker; female (152), herein selected because it has dorsal and anal ray counts agreeing with the original description and because it is the syntype in best condition. Lower jaw length 28.6 mm; P_1–P_2 46.1 mm; P_2–C 70.0 mm; P_2–C extension falls on border of preorbital and orbit; D 15; A 16; P_1 12–12; RGR_1 7 + 20 = 27; RGR_2 5 + 17 = 22; no posterior branch on preorbital canal (Fig. 1 k). Paralectotypes Rijksmus. Nat. Hist. Leiden 6951, 3 (129–134).

Discussion

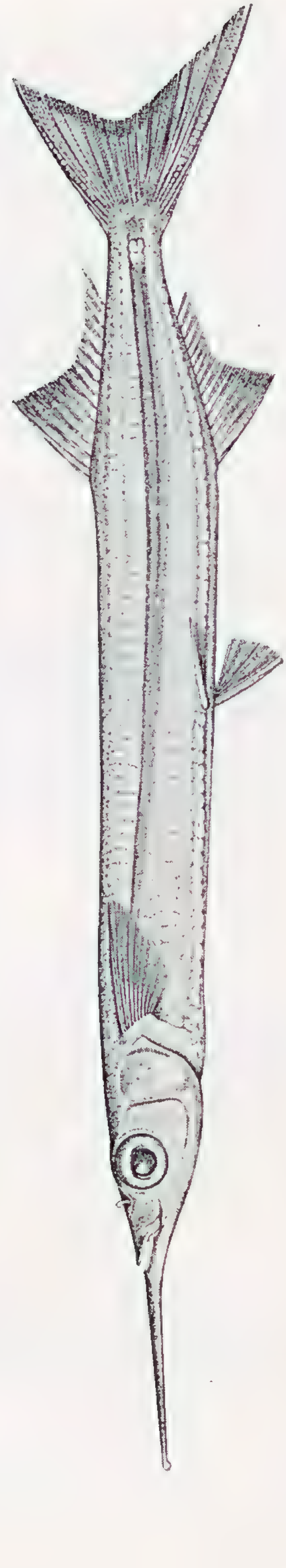
The species of *Hyporhamphus* with an emarginate caudal fin (instead of deeply forked) and without a posterior branch to the preorbital canal are difficult to distinguish. *Hy. regularis* and *Hy. neglectus* are members of this species group along with species such as *Hy. limbatus* (Valenciennes) and the western Atlantic *Hy. unifasciatus* (Ranzani). The name *neglectus* Bleeker is used only tentatively for this Australian species because Bleeker's specimens from the East Indies, and a few small specimens from New Guinea are the only non-Australian specimens that I have examined. It is possible that additional material will show that the Australian species is specifically distinct from *Hy. neglectus*.

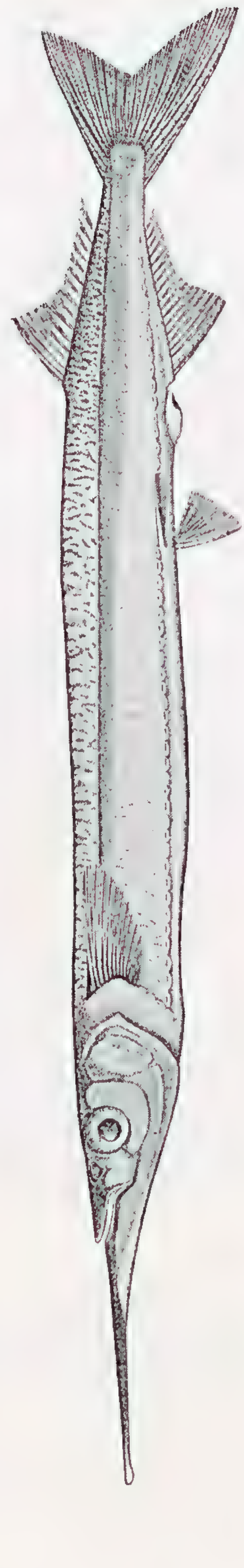
Distribution

Known from the middle of the eastern coast of Queensland, Arnhem Land, Northern Territory, and the northern part of Western Australia (Fig. 12). Severai records from offshore islands. *Hy. neglectus* does not appear to be an estuarine species like *Hy. regularis*. The types are from Indonesia.

Material

111 specimens (15.3–149 mm SL) from 32 collections arranged from south to north and then east to west.





Above.—Figure 14. *Hyporhamphus neglectus*, USNM 173791, 117 mm SL, Groote Eylandt, N.T. *Below.*—Figure 15. *Hyporhamphus australis*, USNM 206581, 262 mm SL, Port Stephens, N.S.W.

Queensland: 38 specimens (29.2–149 mm SL) from 11 collections. AMS IA.6297; Lindeman I., Cumberland Is.; M. Ward; 1 (49.8). AMS IA.2312–15; Townsville; W. E. J. Paradice, HMAS "Geranium"; 4 (98.9–149). CSIRO; Paluma Shoals N. of Bluewater Cr., Townsville; Nov. 24, 1941; 1 (52.4). CSIRO; Missionary Bay near Cape Richards, Hinchinbrook I.; Sept. 22, 1951; 1 (71.2). CSIRO; Goold I. N. of Hinchinbrook I.; Sept. 22, 1951; 3 (40.1–59.0). CSIRO; Flying Fish Point, Innisfail; Feb. 14, 1951; 8 (36.9–63.4). CSIRO; Flying Fish Point, Innisfail; Dec. 14, 1951; 10 (29.2–43.2). CSIRO; Little N. Marrett R., Princess Charlotte Bay; Sept. 27, 1948; 1 (32.7). AMS IB.3159/2762; Karumba, Gulf of Carpentaria; 1 (91.7). AMS IB.3195; Karumba, Gulf of Carpentaria; 1 (90.6). FBQ 2762; Karumba, Gulf of Carpentaria; 7 (81.3–103).

Northern Territory: 59 specimens (20.2–126 mm SL) from 18 collections. USNM 173791; S. end Winchelsea I.; N. Coast Groote Eylandt, Gulf of Carpentaria; R. R. Miller 48–13a; June 6, 1948; 3 (47.4–117). USNM 173792; 2 mi. in from mouth of Port Bradshaw, near Cape Arnhem; R. R. Miller 48–24; July 26, 1948; 11 (45.5–117). USNM 173793; Port Bradshaw near Cape Arnhem; R. R. Miller 48–25; July 23, 1948; 2 (106–117). CSIRO; Truant I., English Company's Is.; July 27, 1949; 1 (80.1). CSIRO 1746; Jensens Bay, Wessel Is.; 1 (112). CSIRO; Jensens Bay, Wessel Is.; July 28, 1949; 6 (47.5–72.2). CSIRO; Mullet Bay, N. Goulburn I.; July 30, 1949; 5 (60.5–82.2). CSIRO C.1747; Port Essington, Cobourg Peninsula; 6 (102–126). CSIRO C.1713; Black Port, Port Essington, Cobourg Peninsula; 1 (110). CSIRO; Port Essington, Cobourg Peninsula; Aug. 1, 1949; 1 (25.4). CSIRO; 15 mi. N.N.W. Cape Don, Cobourg Peninsula; Sept. 17, 1949; 2 (14.0–27.2). CSIRO; off Cape Don, Cobourg Pensinsula; Oct. 16, 1949; 1 (20.2). CSIRO; Gordon Bay, Bathurst I.; Aug. 25, 1949; 1 (26.6). CSIRO; Bathurst I.; Aug. 26, 1949; 1 (20.2). CSIRO C.1739; Gordon Bay, Bathurst I.; 4 (83.1–115). USNM 173790; Nightcliff, 2 mi. N. of Darwin; R. R. Miller 48–2; March 19, 1948; 11 (39.2–64.9). CSIRO C.1719; Peron I., Anson Bay; 1 (117). CSIRO; 1.5 mi. N.E. Peron I., Anson Bay; Oct. 11, 1949; 1 (49.5).

Western Australia: 14 specimens (15.3–116 mm SL) from 3 collections. CSIRO C.1751; Mission Bay, Napier Broome Bay; Aug. 11, 1949; 5 (104–116). CSIRO; Broome; Sept. 25, 1949; 7 (25.8–51.8). CSIRO; Broome; Sept. 27, 1949; 2 (15.3–26.5).

Hyporhamphus australis (Steindachner)

Eastern Sea Garfish

Figs 15–18, Tables 5–6

Hemiramphus australis Steindachner, 1866: 471–2 (original description; Port Jackson, Sydney, N.S.W.). Ogilby, 1916: 10, fig. 10. Marshall, 1964: 101 (in part, N.S.W. and S. Qld.).

Hemirhamphus melanochir.—Castelnau, 1875: 46–7 (small specimen, Qld.). Castelnau, 1879: 394 (in part, Brisbane and Sydney; description probably based on *Hy. melanochir*). (Not *Hemiramphus melanochir* Valenciennes, 1846.)

Hemirhamphus intermedius.—Macleay, 1881: 245 (in part, Port Jackson and Brisbane; description). Tenison-Woods, 1882: 22 (listed), 83–84 (description), pl. 37 (upper fig.). Ramsay, 1883a: 28–9 (N.S.W.; comes in immense schools; favorite breakfast food). Ramsay, 1883b: 4, 19 (after Ramsay 1883a), 45 (listed among 180 N.S.W. food fishes). Ogilby, 1887: 53 (in part, Port Jackson; common garfish of Sydney market; grows to 18 in; excellent table fish). Ogilby, 1889: 71 (Lord Howe Is. [AMS I.1544, 1548], new record). Cohen, 1892: 17 (in part, E. Australia; delicious fish; habits). Ogilby, 1893: 172–3 (synonymy in part; long description; delicious fish; habits), pl. 42. Stead, 1906: 66–7 (in part; description; methods of capture; excellent food fish), fig. 25. Stead, 1907b: 33–4, fig. 9 (eggs). Stead, 1908: 35–6 (one of most valuable N.S.W. food fishes; capture and description after Stead, 1906). Stead, 1911: pl. 2 (huge catch of sea garfish near Sydney). Roughley, 1916: 27–9 (in part;

description, range, habits, food value), colour pl. 4. McCulloch, 1921: 41 (brief description; valuable food fish), pl. 9, fig. 108a. Stead, 1927: 28 (spawns on *Zostera*, Nov.–Feb., Mosman, N.S.W.). (Not *Hemiramphus intermedius* Cantor, 1842.)

Hyporhamphus sp. Waite, 1901: 37 (Lord Howe Is. [AMS I.4617–8], differs from *Hy. intermedius* and *Hy. regularis* of mainland). Waite, 1904a: 187 (Lord Howe Is., same record as Waite, 1901).

Hyporhamphus intermedius.—Waite, 1904a: 194 (Lord Howe Is., synonymy in part). Waite, 1904b: 20 (listed, N.S.W.). Stead, 1907a: 4 (*E. longirostris* captured while seining for *Hy. intermedius*, Bateman's Bay, N.S.W.). Waite, 1909: 381 (Norfolk Is. [AMS I.5407, I.5999], new record, 382 (*Hyporhamphus* listed, Norfolk and Lord Howe Is.). McCulloch and Whitley, 1925: 138 (previous Qld. records). McCulloch, 1929: 102 (in part, N.S.W.). Phillipps, 1932: 230 (in part, mixed with *Hy. melanochir* and compared with *Hy. ihi* Phillipps). Blackburn and Tubb, 1950: 34 (abundance of schools, N.S.W.), 35 (table 19a, percentage of positive weekly reports for 8 N.S.W. localities, analysis of reports; table 19c, seasonal maximum occurrence, Feb.–March). Roughley, 1951: 22–3 (in part; description; reaches 18 in.; N.S.W. catch 1948–9 81,000 lbs), colour pl. 5 (from Roughley, 1916).

Hemirhamphus australis.—McCulloch, 1921: 41 (after Steindachner, 1866; not recognized since first described). Munro, 1957: 56 (description; N.S.W., Qld., and possibly N. Vic.), fig. 400. Thomson, 1959a: 356 (small contribution to catch, Lake Macquarie, N.S.W. in some years). Thomson, 1959b: 366 (table 1, listed, Lake Macquarie, N.S.W.), 370 (table 3, list of omnivores, algae and crustaceans present in over 80% of stomachs). Grant, 1965: 38 (brief description, after Munro, 1957; N.S.W. and S. Qld.; important bait fish), fig. (*Hy. melanochir* after McCoy, 1887). Grant, 1972: 64 (repeat of 1965 ed.).

Hyporhamphus australis.—McCulloch, 1929: 102 (listed, N.S.W.).

Reporhamphus australis.—Whitley, 1931a: 314 (type-species of *Reporhamphus* Whitley; distinguished from *R. melanochir* and *R. ardelio*). Weed, 1933: 59–60 (validity of *Reporhamphus* Whitley). Whitley, 1935a: 300 (ocean beach zone fish, Sydney). Whitley, 1935b: 341 (Port Stephens, N.S.W. specimen [AMS IA.6102] with rubber band around body), fig. Whitley, 1941: 341 (Tuggerah Lakes, N.S.W. specimens [AMS IB.731–2] with rubber bands around body). Whitley, 1962: 54–5 (exquisite table-fish), fig. (after Stead). Whitley, 1964b: 38 (listed).

Diagnosis

The three species of sea garfishes (*Hy. australis*, *melanochir*, and *ihi*) differ from the river garfishes (*Hy. r. regularis* and *Hy. r. ardelio*) in a number of characters. The sea garfishes have a posterior branch to the preorbital canal which is absent in the river garfishes (compare Fig. 2, a–g with Fig. 1, g–j). The posterior branch is on an almost straight line with the anterior branch, both posterior and ventral branches are narrow and the posterior and ventral pores are small compared to other Australian fork-tailed garfishes such as *Hy. quoyi* (Fig. 2, l–n). The upper jaw is pointed and about as long as wide in the sea garfishes, rounded and wider than long in the river garfishes (width divided by length 0.82–1.49, means 1.00, 1.16, and 0.94 for the sea garfishes vs. 1.11–1.92, means 1.56 and 1.69 for the river garfishes). The scales are deciduous and usually absent in market and museum sea garfishes contrasted to usually present, at least in market specimens, in river garfishes. These three species differ from *Hy. dussumieri* in having the maximum body depth distinctly greater than the width instead of about equal, width divided by depth 0.47–0.90.

Table 5. Number of fin rays, gill-rakers and vertebrae in populations of *Hyporhamphus australis*, *Hy. melanochir*, **and** *Hy. ihi* **(* in New South Wales and S. Australia columns indicates holotype of** *Hy. australis* **and lectotype of** *Hy. melanochir* **respectively)**

Species and Population	Fin Rays														
	Dorsal						Anal						Pectoral		
	15	16	17	18	N	x̄	17	18	19	20	N	x̄	11	12	13
Hy. australis															
Norfolk I.	..	1	1	..	2	16.50	..	..	2	..	2	19.00	..	2	..
Lord Howe I.	..	3	6	..	9	16.67	..	5	4	..	9	18.44	4	2	1
New South Wales	29*	68	10	..	107	15.82	12	63*	24	2	101	18.16	26	43	..
Hy. melanochir															
Victoria	1	28	33	2	64	16.56	..	19	37	8	64	18.83	4	17	..
Tasmania	1	12	19	1	33	16.61	..	13	17	2	32	18.66	3	19	..
S. Australia	2	31	32*	..	65	16.46	2	25	38*	..	65	18.55	..	30*	..
W. Australia	6	54	19	..	79	16.16	4	56	17	2	79	18.22	10	46	1
Hy. ihi															
New Zealand	20	64	16	2	102	16.00	12	64	23	3	102	18.17	14	28	..

Species and Population	First Arch Gill-rakers														
	27	28	29	30	31	32	33	34	35	36	37	38	39	N	x̄
Hy. australis															
Norfolk I.	..	..	..	..	1	..	..	..	..	..	..	..	..	1	31
Lord Howe I.	..	..	..	..	..	..	2	3	1	3	..	..	..	9	34.55
New South Wales	..	..	..	..	3	6	9	16	23*	28	10	6	2	103	35.10
Hy. melanochir															
Victoria	1	2	11	15	14	11	6	..	..	..	..	..	..	60	30.60
Tasmania	..	1	4	7	11	6	4	..	..	..	..	..	..	33	30.88
S. Australia	..	..	1	8	13	13*	2	3	1	..	..	..	..	41	31.49
W. Australia	..	..	3	13	18	19	9	4	..	..	..	..	..	66	31.45
Hy. ihi															
New Zealand	3	13	11	19	6	3	1	..	..	..	..	..	..	56	29.45

Table 5—*continued*

	Second Arch Gill-rakers														
	21	22	23	24	25	26	27	28	29	30	31	32	33	N	$\bar{x}$
Hy. australis															
Norfolk I.	..	..	..	..	..	..	..	1	..	..	..	..	..	1	28
Lord Howe I.	..	..	..	..	..	1	3	3	1	1	..	..	..	9	27.78
New South Wales	..	..	1	..	7	6	10	16	16	19	17*	6	2	100	28.91
Hy. melanochir															
Victoria	1	5	10	17	20	4	2	..	..	..	..	..	..	59	24.19
Tasmania	..	..	2	8	11	8	..	1	..	..	..	..	..	30	24.97
S. Australia	..	..	1	6*	13	11	3	3	..	..	..	..	..	37	25.49
W. Australia	..	1	1	8	26	16	6	6	1	..	..	..	..	65	25.57
Hy. ihi															
New Zealand	9	11	14	13	6	..	..	..	..	..	..	..	..	53	22.92

	Total Vertebrae								
	55	56	57	58	59	60	61	N	$\bar{x}$
Hy. australis									
New South Wales	..	7	33	10	..	..	..	50	57.06
Hy. melanochir									
Victoria	..	..	..	6	3	2	..	11	58.64
Tasmania	..	..	..	6	7	7	2	22	59.23
S. Australia	..	..	2	11	12	1	..	26	58.46
W. Australia	1	2	17	23	2	..	..	45	57.51
Hy. ihi									
New Zealand	7	35	12	3	..	..	..	57	56.19

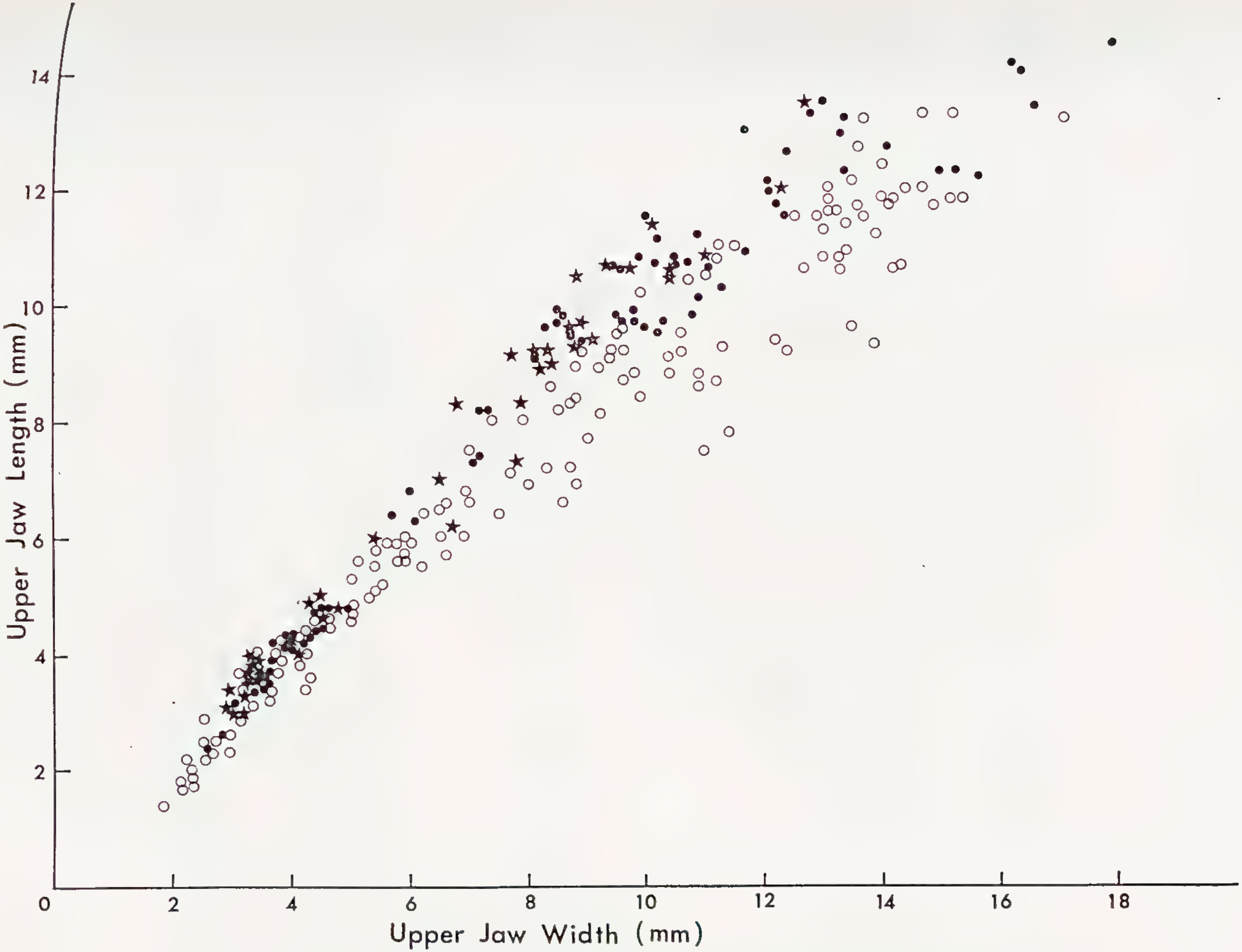


Figure 16. Relationship of upper jaw length to upper jaw width in three species of *Hyporhamphus*. Dots = *Hy. australis*; open circles = *Hy. melanochir*; and stars = *Hy. ihi*.

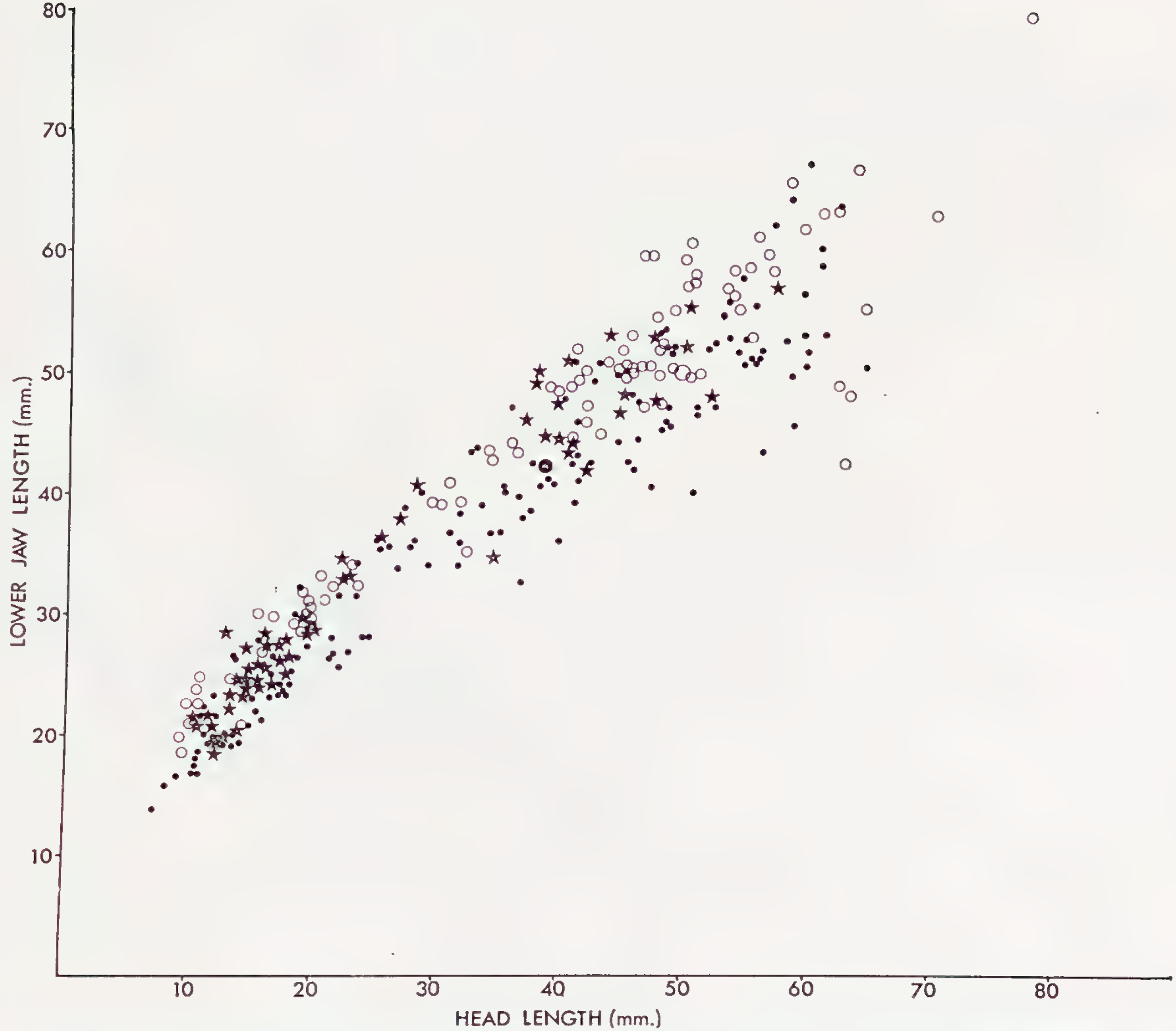


Figure 17. Relationship of lower jaw length to head length in three species of *Hyporhamphus* (dots = *Hy. melanochir;* open circles = *Hy. australis;* stars = *Hy. ihi;* large symbols = types).

Hy. australis differs from its two closest relatives, *Hy. melanochir* and *Hy. ihi*, primarily in having more gill-rakers (Table 5), usually 34 or more on the first arch (compared with usually 33 or less in both *Hy. melanochir* and *Hy. ihi*), and usually 27 or more on the second arch (usually 26 or less). Both *Hy. australis* and *Hy. ihi* have relatively longer upper (Fig. 16) and lower jaws (Fig. 17) than does *Hy. melanochir*, especially at larger sizes.

Description

Upper jaw long and pointed, longer than wide at small sizes, shorter than upper jaw width at larger sizes (Fig. 16); width divided by length 0.86–1.29, $\bar{x}$ 1.00. Lower jaw length moderate, usually slightly longer than head length (Fig. 17); head length divided by lower jaw length 0.62–1.32, $\bar{x}$ 0.89 over entire size range. Pelvic fins placed about midway between pectoral and caudal bases; P_2–C distance divided by P_1–P_2 0.81–1.04, $\bar{x}$ 0.93; P_2–C extension falls on opercle to mid-adpressed pectoral fin, usually on the anterior third of the adpressed pectoral. Dorsal rays 15–17, usually 16; anal rays 17–20, usually 18; pectoral rays 11 or 12, rarely 13 (Table 5). Vertebrae (37–39) + (18–20) = 56–58, usually 38 + 19 = 57. Gill-rakers on first arch (9–12) + (22–28) = 31–39, usually 34–37; on second arch (4–7) + (19–27) = 23–33, usually 27–31. Length of dorsal fin base greater or equal to length of anal fin base (dorsal base divided by anal base 0.97–1.13, $\bar{x}$ 1.04).

Maximum known size

398 mm SL (AMS IA.6543, Tuggerah Lake, N.S.W.).

Holotype

NHMV 5560, 236 mm SL, Port Jackson. D 15; A 18; P_1 11–12; RGR_1 10 + 25 = 35; RGR_2 5 + 26 = 31; lower jaw length 49.8 mm; head length 49.7 mm; P_1–P_2 98.6 mm; P_2–C 88.3 mm; P_2–C extension falls on anterior third of adpressed pectoral fin; preorbital canal shown in Fig. 2a.

Discussion

Hy. australis and *Hy. melanochir* are considered as species rather than subspecies because the diagnostic characters of the species do not show any trace of intergradation in the geographically closest large samples, Moruya, N.S.W. (*Hy. australis*) and Melbourne (*Hy. melanochir*). Two of four specimens from Eden appear to be *Hy. australis*, the third *Hy. melanochir*, and the fourth a hybrid between the two. This is discussed at greater length under the account of the latter species.

The populations of *Hy. australis* at Norfolk and Lord Howe islands do not appear to differ significantly from the mainland population but it would be worthwhile to have larger samples available for a more thorough comparison.

Distribution

An eastern Australian endemic found from Moreton Bay, Qld. to Eden, N.S.W. (Fig. 18) and also at Lord Howe and Norfolk islands. The southern distribution of *Hy. australis* meets the eastern range of *Hy. melanochir* at Eden.

Material

186 specimens (50.4–398 mm SL) from 45 collections, arranged from north to south.

Queensland: QM I.7099; Moreton Bay; 1 (220).

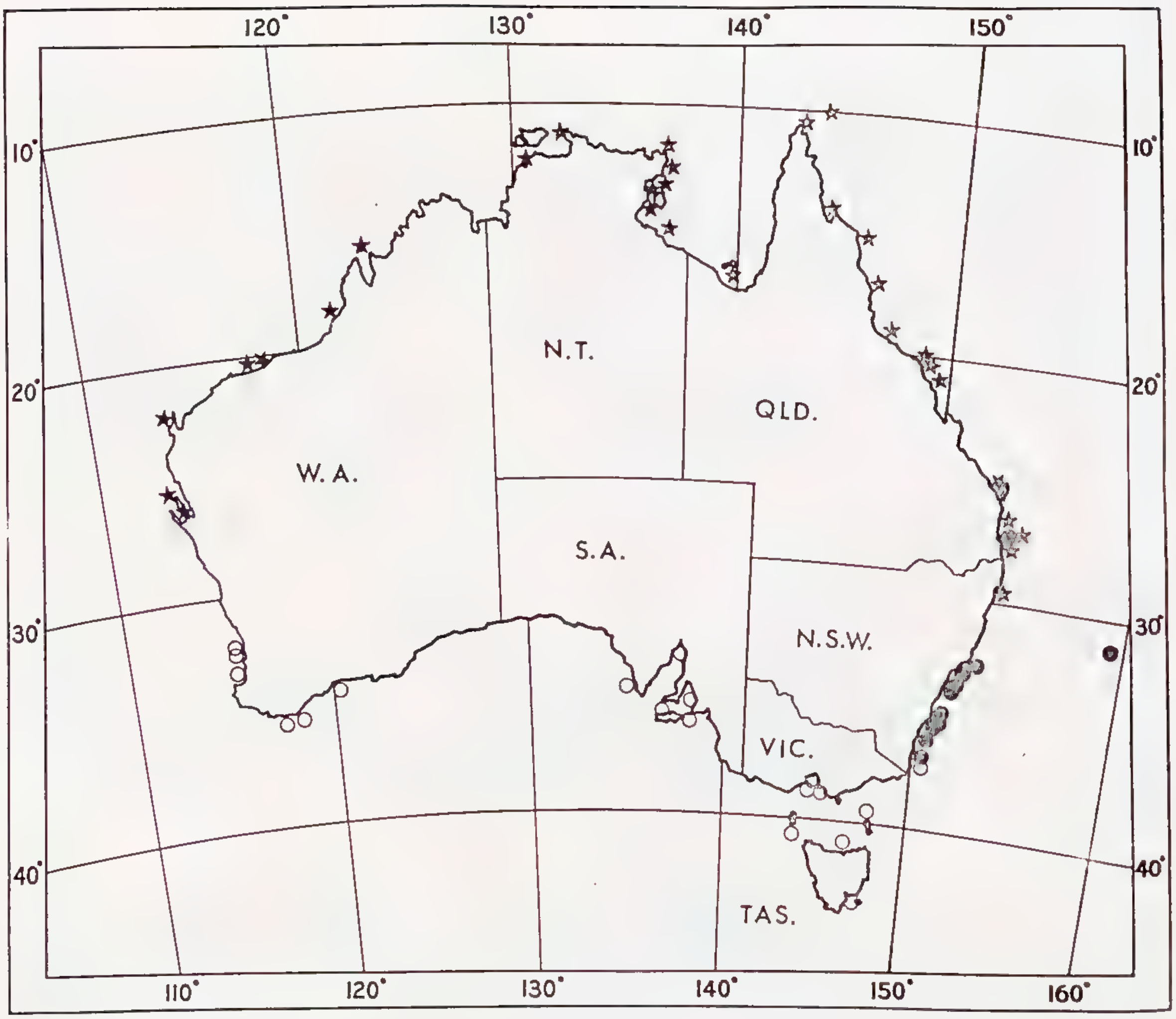


Figure 18. Distribution of three species of *Hyporhamphus* (dots = *Hy. australis*, open circles = *Hy. melanochir*, stars = *Hy. quoyi*) around Australia, based on specimens examined.

New South Wales: 174 specimens (50.4–398 mm) from 36 collections: BBC 1427; Port Stephens; Sydney mkt.; B. B. Collette and J. R. Paxton; Jan. 22, 1970; 63 (194–280); 5 spec. at SAM, 5 at WAM, 20 at AMS, 3 at BMNH 1970.7.28.11–13, 3 at MNHN, remainder USNM 206581. AMS I.9853–4; Port Stephens; R. Thorpe; March 1909; 2 (260–296). AMS IA.6102; North Head, Port Stephens; N.S.W. Fish. Dept; Aug. 1934; 1 (218). AMS IA.6543; Tuggerah Lake; D. G. Stead; 1 (398). AMS IB.731–2; Tuggerah Lake; T. C. Roughley; June 21, 1941; 2 (259–303). NHMV 5560; Port Jackson, Sydney; 1 (236); holotype of *He. australis*. USNM 47839; Port Jackson, Sydney; 3 (217–222). SU 20981; Port Jackson, Sydney; orig. AMS I.4616; 4 (152–293). ZMUC CN 5–6; Port Jackson; Th. Mortenson; March 3, 1915; 2 (145–147). MNHN 4079; Sydney; Castelnau; 1879; 2 (225–242). MNHN A.4068; Sydney; Castelnau; 1879; 1 (195). MNHN A.4077; Sydney; Castelnau; 2 (200–240). NHMV 5572; Sydney; Steindachner; 1874; 2 (207–215). IRSNB 1521; Port Jackson; exchange Sydney Mus., 1882; 2 (174–175). IRSNB 1228; same data; 1 (226). IRSNB 654; same data; 6 (200–250). AMS I.1142; Port Jackson, Sydney; Sydney mkt.; March 1887; 1 (248). BMNH 1890.9.23.195–8; Port Jackson; 5 (222–308). AMS I.4483; locality ?; Sydney mkt.; Aug. 1900; 1 (268). BMNH 1883.11.29.83; Sydney Mus.; 1 (268). AMS I.9525–6; near Sydney; N.S.W. Fish. Dept; 2 (234–240). AMS IB.1418; Dee Why, Sydney; G. P. Whitley; April 26, 1945; 1 (91.2). AMS IB.2681; Camp Cove, Sydney; D. G. Stead; 1 (71.1). ZMH 1771; Watson's Bay, Sydney; P. Timm; April 20–May 17, 1914; 5 (220–243). AMS I.9847; Maroubra Beach, Sydney; Fry and Kinghorn; Feb. 1909; 1 (95.0). AMS IB.7503; Coal Cliff; K. D. Williams; 1 (332). USNM 59961; Port Hacking; 1901; D. G. Stead; 1 (325). USNM 206580; Nowra, Shoalhaven R.; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1377; Nov. 12, 1969; 4 (171–314). USNM 206585; Nowra; Sydney mkt.; B. B. Collette 1460; March 19, 1970; 8 (179–237). USNM 59977; Crookhaven R.; 1904; D. G. Stead; 3 (141–144). CSIRO; Crookhaven R. entrance; April 22, 1939; 10 (50.4–80.3). CSIRO; Crookhaven R. entrance; Dec. 25, 1939; 3 (110–118). CSIRO; Jervis Bay; March 5, 1954; 17 (78.2–158). USNM 206583; Ulladulla; Sydney mkt.; B. B. Collette 1460; March 19, 1970; 3 (215–224). USNM 206584; Moruya; Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1453; Feb. 26, 1970; 10 (166–195). ZMUC 307; "New South Wales"; Th. Steel; 1 (171).

Lord Howe Island: 9 specimens (64.1–301 mm) from 6 collections: AMS I.4089; E. R. Waite; 1898; 1 (262). AMS I.5567–8; Waite and McCulloch; Feb. 1903; 2 (290–301). SU 9217; orig. AMS I.5565; 1 (296). AMS I.1544, 48; R. Etheridge; Nov. 1887; 2 (216–260). AMS I.4617–8; F. Farnell; Sept. 1900; 2 (64.1–83.1). AMS IB.6387; J. Booth; 1 (71.1).

Norfolk Island: AMS I.5407; F. A. Allen and H. Quintal; Nov. 1902; 1 (296). AMS I.5999; G. E. Nobbs; April, 1903; 1 (302).

Hyporhamphus melanochir (Valenciennes)

Southern Sea Garfish

Figs 16–18, Tables 5–7

Hemiramphus sp. Richardson, 1840: 30 (Port Arthur, Tas.). Richardson, 1842: 108 (Port Arthur, Tas.).

Hemiramphus melanochir Valenciennes *in* Cuvier and Valenciennes, 1846: 41–2 (original description; Port Western, New Holland = Adelaide, S. Australia; misspelled "*malanochir*" on p. 41, spelled correctly in table of contents). Castelnau, 1872: 179–80 (description; one of commonest food fishes in Melbourne markets at all seasons). Scott, 1962: 78 (description; one of most important S.A. food fishes), fig. Kabata, 1966: 568 (record of copepod *Gloiopotes huttoni* from Adelaide: doubtful—see parasites section). Lakin, 1968: 252; 1969: 268; 1970: 312; and 1971: 283, 287 (catch in Tas.).

Hemirhamphus intermedius.—Günther, 1866: 260–1 (in part, specimens from Tas. [BMNH unreg.] and S.A.; *He. melanochir* placed in synonymy). Macleay, 1881: 245 (in part, specimens from Melbourne and W.A.; description). Johnston, 1883: 56–7 (market fish in Tas.), 91 (abundant in shallow estuaries in summer, highly esteemed in market), 132 (brief description). Johnston, 1891: 23 (abundant, Tas. markets), 27 (one of principle edible Tas. species), 36 (description), 42 (size limits—8 in.), 43 (10,229 doz. sold, Hobart market,

1888). Ogilby, 1893: 172–3 (in part; synonymy, range, habits). Waite, 1900: 210 (Swan R. near Perth [AMS I.4199], W.A.). Stead, 1906: 66–7 (in part, description). Zietz, 1909: 263 (in part; Vict., Tas., S.A., W.A.). Roughley, 1916: 27–9 (in part; description; food value; life history). Lord, 1923: 65 (listed, Tas.). Lord and Scott, 1924: 8 (listed), 42 (description; Tas.; valuable food fish). Phillipps, 1927a: 21 (range and synonymy in part). Jowett and Davies, 1938: 7 (Vict., suitable for conversion into meal), 13, 34 (table 11, chemical composition of 20 fillets), 35 (low fat content fish). (Not *Hemiramphus intermedius* Cantor, 1842.)

Hemiramphus intermedius.—Klunzinger, 1872: 42 (Hobsons Bay, [Melbourne, SMN 2190, 1578], Vict.). Klunzinger, 1880: 414 (Hobsons Bay, Vict.). McCoy, 1887: 113–4 (long description, Vict.), colour pl. 135, fig. 1. Lucas, 1890: 36 (listed, Vict.). Fowler, 1919: 7 (description; Vict.). Fowler, 1923: 43 (Melbourne market [ANSP 49307–9]). Lord, 1927: 13 (Tas., listed). Heegaard, 1962: 185 (copepod *Lernaeenicus hemiramphi* from St Vincent Gulf, S.A. specimen).

Hemirhamphus melanochir.—Castelnau, 1873: 143 (Fremantle, W.A.; green vertebrae). Castelnau, 1879: 355 (listed), 394 (description; Swan R., W.A.; Melbourne [MNHN A.4077, A.4079, A.4068]). Munro, 1957: 56 (description; Vic., S.A., Tas., and W.A.), fig. 401 (after McCoy, 1887). Lynch, 1966: 10 (taken by beach seines; Port Phillip Bay, Vict.), 11–12 (annual catch 1951–60 varied from 3,283 to 10,319 lbs; Port Phillip Bay).

Hyporhamphus intermedius.—Waite, 1921: 65 (S.A.; description; synonymy in part; breakfast fish), fig. 98. Waite, 1923: 89 (S.A.; description), fig. Hale, 1926: 222 (cymothoid isopod *Irona melanosticta* under gill covers of 18 S.A. specimens). Waite, 1928: 5 (S.A., listed). Hale, 1929: 263 (*Irona melanosticta* under gill covers). McCulloch, 1929: 102 (in part; S.A., Vict., Tas., and W.A.). Phillipps, 1932: 230 (in part, compared with *Hy. ihi*). Guest and Robertson, 1939: 179 (excellent edible fish), 181 (Sir Joseph Banks Is., Spencer Gulf, S.A.). Campbell *et al.*, 1946: 484 (used as food by aborigines in southeast S.A.). Roughley, 1951: 22–3 (in part).

Reporhamphus melanochir.—Whitley, 1931a: 314 (placed in new genus *Reporhamphus* Whitley; distinguished from *R. australis*). Weed, 1933: 59 (comments on genus *Reporhamphus*). Whitley, 1946: 27 (Esperance, W.A.). Whitley, 1948: 15 (listed, Esperance to Shark Bay, W.A.). Beck, 1956: 16 (14–17 ppm dry weight concentration of copper in livers of 2 spec. from Busselton, W.A.). Thomson, 1957a: 4–6 (stomach contents 301 W.A. specimens; 70% contained *Zostera*), 8 (in stomach of *Arripis georgianus*). Thomson, 1957b: 4–8 (299 W.A. specimens; gonad development; 1,280–3,000 eggs; males mature at 24.5 cm., females at 24.6 cm.). Ling, 1958: (S.A.; breeding; age determination; growth rate). Whitley, 1964b: 38 (listed).

Hyporhamphus australis.—Tortonese, 1939: 255–7 (Melbourne; discussion of validity of *Reporhamphus;* no mention of the name *Hy. melanochir*). (Not *Hemiramphus australis* Steindachner, 1866.).

Hemiramphus australis.—Marshall, *et al.*, 1959: 28 (fig. of *Hy. melanochir* after McCoy, 1887). Marshall, 1964: 101 (in part, valuable food fish in S. Australian states).

Hemiramphus australis.—Grant, 1965: 38 (fig. of *Hy. melanochir* after McCoy, 1887).

Diagnosis

Hy. melanochir differs from *Hy. australis* and resembles *Hy. ihi* in having fewer gill-rakers (Table 5), usually 33 or less on the first arch (compared with usually 34 or more in *Hy. australis*) and usually 26 or less on the second arch (usually 27 or more). *Hy. melanochir* differs from both *Hy. australis* and *Hy. ihi* in having a relatively shorter upper and lower jaw, especially at larger sizes (shorter than upper jaw width and head length, respectively, Figs 16 and 17). The pelvic fins are further posterior in *Hy. melanochir*, the P_2–C extension usually falling on the adpressed pectoral fins instead of on the opercle or pectoral fin base as in *Hy. ihi*.

Description

Upper jaw long and pointed, as long as wide at smaller sizes, shorter than wide at larger sizes (Fig. 16); width divided by length 0.84–1.49, population means over entire size range 1.02–1.16. Lower jaw length moderate, usually slightly longer than head length until about 200 mm SL when it becomes about equal to head length (Fig. 17); head length divided by lower jaw length 0.49–1.29, population means over entire size range 0.73–0.96. Pelvic fins placed about midway between bases of pectoral and caudal fins; P_2–C distance divided by P_1–P_2 0.78–1.11, population means 0.91–0.94; P_2–C extension falls on opercle to mid-adpressed pectoral fin, usually on the anterior third of the adpressed pectoral fin. Dorsal rays 15–18, usually 16 or 17; anal rays 17–20; usually 18 or 19; pectoral rays 11–13, usually 12. Vertebrae (36–41) + (18–21) = 55–61, lower counts to the west. Gill-rakers on first arch (7–11) + (20–25) = 27–35, usually 30–32; on second arch (2–6) + (18–25) = 21–29, usually 23–26. Length of dorsal fin base equal to anal fin base, or slightly longer; dorsal base divided by anal 0.96–1.17, population means 1.03–1.06.

Maximum known size

332 mm SL (BMNH 1896.6.17.80–84, Melbourne Market).

Lectotype

MNHN B.1066, female, 184 mm SL, Port Western, New Holland (= Adelaide, S. Australia); Quoy and Gaimard; herein selected. This specimen is the largest of the three syntypes, is in the best condition, bears the original tag, and has a dorsal and anal ray count (17–19) that matches Valenciennes' original description. Gill-rakers on first arch 9 + 23 = 32; on second arch 4 + 20 = 24; lower jaw length 42.2 mm; head length 38.2 mm; P_1–P_2 76.0 mm; P_2–C 69.7 mm; P_2–C extension falls on anterior third of adpressed pectoral fin. Preorbital canal with posterior branch (Fig. 2d). Paralectotypes; MNHN B.2636; 2 (148–163); removed from B.1066.

Geographic variation

Meristic data for populations of *Hy. melanochir* in the four southern states are presented in Table 5. There is a decreasing cline in vertebral number from Victoria west to W. Australia. The populations in Victoria and Tasmania are more similar to each other than to the populations in S. Australia and W. Australia in number of gill-rakers but there is some evidence of a clinal increase toward the west. Fin-ray counts are essentially the same throughout the range.

Morphometrically, there is also evidence of two groups of populations. Comparison of regressions of eight characters between adjacent states (Table 7) shows that the only significant differences were in lower jaw length and P_2–C distance between Victoria and S. Australia.

Table 6. Comparison of regression equations and F values for slopes and heights of eight morphometric characters for three species of *Hyporhamphus* (= Significant at 99.9% level)**

Character	Regression Equations Y =			F values					
	Hy. australis	*Hy. melanochir*	*Hy. ihi*	*Hy. australis* vs. *Hy. melanochir*		*Hy. australis* vs. *Hy. ihi*		*Hy. melanochir* vs. *Hy. ihi*	
				Slopes	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*
Lower jaw length ..	0.1368X + 17.528	0.1555X + 12.334	0.1682X + 12.679	3.74	2.74	6.72	0.136	1.52	10.41
Head length	0.0255X − 0.151	0.2126X − 1.014	0.2089X − 0.511	4.66	2.00	0.578	0.176	0.656	0.149
P_1–P_2	0.4271X − 2.103	0.4255X − 2.046	0.4188X − 2.460	0.241	− 0.612	1.66	11.01	1.30	10.30
P_2–C	0.3757X + 1.014	0.3638X + 2.166	0.3818X + 1.025	6.71	6.06	0.967	4.74	10.27	16.22**
Base dorsal fin	0.1380X + 0.718	0.1344X + 1.688	0.1416X + 1.170	2.60	2.70	0.770	10.53	7.51	9.12
Base anal fin	0.1277X + 1.468	0.1205X + 2.665	0.1320X + 1.788	8.28	0.018	1.99	17.75**	14.05**	(14.67)
Upper jaw length ..	0.0401X + 0.521	0.0439X − 0.331	0.0488X − 0.411	6.65	2.14	21.47**	6.11	7.08	26.94**
Upper jaw width ..	0.0478X − 0.596	0.0544X − 1.213	0.0458X − 0.401	19.27**	(15.48)	1.55	0.776	18.92**	10.66
Degrees of freedom ..				1, 143–171		1, 53–63		1, 151–174	

Discussion

Hy. melanochir and *Hy. australis* are considered as species rather than as subspecies because their ranges meet at Eden, New South Wales and because the most important differentiating characters, numbers of gill-rakers and vertebrae, show no trace of intergradation in the geographically closest large samples, Moruya, New South Wales (*Hy. australis*) and Melbourne, Victoria (*Hy. melanochir*). In fact, the Melbourne population has even fewer gill-rakers (mean number on first arch 30.64, second arch 24.18) than other populations of *Hy. melanochir*. For the Adelaide population, the mean number of gill-rakers on the first arch is 31.62, second arch 26.00; for all specimens of *Hy. melanochir* (except the Melbourne population) the means are 31.38 and 25.33. Similarly, the Victoria population of *Hy. melanochir* has distinctly more vertebrae than does *Hy. australis* while the W. Australian population completely overlaps the range of *Hy. australis*.

This character displacement in number of gill-rakers and vertebrae indicates that the species are maintaining their identity as they approach each other geographically. Presumably, Tasmania was once connected to Victoria across Bass Strait thus dividing a continuous population of *Hyporhamphus* into an eastern population which differentiated into *Hy. australis*, and a western population which differentiated into *Hy. melanochir*. A similar split between eastern and western populations of the Australian "salmon", *Arripis trutta*, has been described by Malcolm (1959, 1960), but in this case the populations are only subspecifically distinct, mix somewhat out of the breeding season, and maintain their identity by migrating to separate breeding areas.

The presence of both species at Eden deserves special mention. Four specimens were selected, more or less at random, from several boxes of large sea garfish in the Sydney Fish Market on 8 April, 1970. The smallest of the four (266 mm SL) was quickly separated from the other three on the basis of low gill-raker counts. The three larger specimens had a more prominent ridge in the middle of the upper jaw than the smallest one. There was more yellow on the anterior edge of the anal fin in the smallest, a moderate amount in one specimen, and much less in the remaining two. Otoliths were extracted from the fresh specimens: two sets were of one species, one set (the smallest specimen) was of a second species, and the third set was intermediate. Two specimens have 57–58 total vertebrae, the smallest specimen has 60, and the fourth has 59. I conclude (Collette, 1973) that the smallest specimen is *Hy. melanochir*, two others are *Hy. australis*, and the fourth specimen is a hybrid between the two.

Distribution

Known from Tasmania and from Melbourne, Victoria west along the Great Australian Bight into the Indian Ocean north as far as Perth, Western Australia (Fig. 18). One specimen of four from Eden, New South Wales appears to be *Hy. melanochir*, two others *Hy. australis*, and the fourth a hybrid between the two species (see above).

Material

306 specimens (38.1–332 mm SL) from 63 collections arranged from north to south and then east to west.

New South Wales: USNM 207521; Eden; purch. Sydney mkt.; B. B. Collette and J. R. Paxton; BBC 1466; April 8, 1970; 1 (266).

Tasmania, 33 specimens (58.9–277 mm) from 8 collections: MCZ 697; Hobart; Robertson; 8 (126–144). CSIRO; West Sister Is., Furneaux Group; Oct. 8, 1952; 5 (60.7–88.8). CSIRO; Seal Bay, King Is.; Sept. 7, 1952; 1 (58.9). USNM 206557; Green's Beach at mouth Tamar R.; R. H. Green; Jan. 18, 1969; 5 (122–189). USNM 206556; same locality and collector; Jan. 1970; 7 (93.2–147). AMS B.5527, 5530; Tasmania; exch. Hobart Mus.; Dec. 1884; 2 (236–277). BMNH pre-reg.; Van Dieman's Land; Melville; 2 (183–193). BMNH 1875.10.12.18–20; Tasmania; M. Allport; 3 (212–220).

Victoria, 70 specimens (61.6–332 mm) from 14 collections: AMS I.7506–12; Queenscliffe, near Melbourne; E. R. Waite; Nov. 1905; 47 (61.1–227). MNHN 1177; Port Phillip, Melbourne; Müller; 2 (208–261). MNHN 1416; Port Phillip, Melbourne; Dec. 1862; 1 (297). MNHN 4249; Melbourne; Müller; 1 (216). SMN 2190 + 1578; Hobsons Bay, Port Phillip; Müller; 2 (218–251). MNHN 84–371; Melbourne Museum; 1884; 1 (257). NHMV 5600; Melbourne; McCoy; 1882; 1 (260). BMNH 1896.6.17.80–84; Melbourne mkt.; Degen; 5 (280–332). MCZ 8772; Melbourne; F. Müller; recd. April 1886; 1 (107). AMS I.7547; Melbourne mkt.; E. R. Waite; Nov. 1905; 2 (240–269). ANSP 49307–9; Melbourne mkt.; A. F. Kenyon; 1909; 3 (245–271). USNM 176998; Hastings, near Melbourne; J. K. Howard; March 15–17, 1953; 1 (200). CSIRO; Rye, near Melbourne; Aug. 21, 1941; 2 (94.3–97.4). MCZ 8776; "Victoria"; 1 (306).

South Australia, 84 specimens (37.0–307 mm) from 14 collections. MNHN B.1066, lectotype; and MNHN B.2636, paralectotypes of *He. melanochir*; Port Western (=Adelaide); Quoy and Gaimard; 3 (148–184). USNM 206586; Port Adelaide; purch. Adelaide mkt.; B. B. Collette and J. R. Paxton; BBC 1430; Feb. 3, 1970; 10 (231–279). AMS A.17619–21; Adelaide; G. Bealey; July 1883; 3 (216–282). ZMK P341781–9; off Adelaide; Galathea 567; Dec. 7, 1951; 9 (77.5–208). AMS IB.1046; W. River, Kangaroo Is.; CSIRO; Feb. 23, 1939; 6 (50.0–81.8). AMS IB.1057; same data as IB.1046; 8 (38.1–63.7). USNM 177167; around Kangaroo Is. and St Stephens Bay; J. K. Howard; March 25–April 18, 1953; 5 (148–233). CSIRO; Antechamber Bay, Kangaroo Is.; Feb. 28, 1939; 8 (49.3–138). CSIRO; Antechamber Bay, Kangaroo Is.; March 7, 1953; 4 (45.7–77.4). USNM 206566; Spencer Gulf at Port Augusta Caravan Park; B. B. Collette and J. R. Paxton; BBC 1431; Feb. 3, 1970; 2 (116). ZMH uncat.; Spencer Gulf; H. Nissen; 1901; 18 (37.0–79.2). AMS IA.7101–2; "South Australia"; G. Bourne; 2 (300–307). SAM 1141; "South Australia", perhaps St Vincent Gulf; 2 (211–235). CSIRO; Coffin Bay; April 28, 1949; 4 (58.8–95.9).

Western Australia, 112 specimens (57.7–294 mm) from 22 collections: CSIRO C.2648; Hopetoun; March 6, 1952; 1 (197). AMS IA.667–8; King George Sound, Albany; Troughton, Grant, and Wright; April 1922; 2 (210–230). NHMV 5601; Albany; 2 (227–228). CSIRO C. 2528–9; Albany Harbour; Oct. 10, 1954; 2 (211–240). AMNH 40005; N. edge Two Peoples Bay, near Albany; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–21; March 14, 1969; 2 (59.9–189). WAM P–7900; Denmark Estuary; J. Ride; Jan. 10, 1964; 1 (178). USNM 206565; Leschanault Estuary at Koombana Caravan Park, Bunbury; B. B. Collette and J. R. Paxton; BBC 1437; Feb. 7, 1970; 1 (81.2). WAM P–6129; Bunbury; W. H. Graham; March 2, 1963; 1 (79.3). USNM 206564; Bunbury Bay at Koombana Park, Bunbury; B. B. Collette and J. R. Paxton; BBC 1442; Feb. 8, 1970; 2 (86.4–90.8). BBC 1448; Mandurah; purch. Perth mkt.; B. B. Collette, J. R. Paxton, R. J. McKay; Feb. 13, 1970; 23 (213–294); 4 spec. to AMS; 3 to BMNH (1970.7.28.8–10); 3 to MNHN; remainder to USNM 206587. USNM 206567; Shoalwater Bay, near Point Peron; B. B. Collette and J. R. Paxton; BBC 1445; Feb. 11, 1970; 3 (66.0–106). AMNH 40004; Point Peron, Cockburn Sound; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–43; March 23, 1969; 45 (67.5–182). USNM 206569; Mangles Bay, Cockburn Sound; B. B. Collette and J. R. Paxton; BBC 1444; Feb. 9, 1970; 6 (65.0–115). WAM P–98; Garden Island; Jan. 1914; 1 (166). WAM P–13408–13; Rottnest Is. off Perth; M. Bartlett; March 7, 1963; 6 (214–291). AMS I.4199; Swan R., Perth; exch. Perth Mus.; May 1899; 1 (292). ZMH uncat.; Fremantle; W. Wölting; 1907; 1 (102). AMS I.13244–6; Fremantle; W.A. Fish. Dept; Aug. 1914; 3 (204–232). WAM P–308; Fremantle; Fish. Inspector; July 1915; 2 (248–290). WAM P–2574–5; Whitford Beach, Perth; W.A. Fish. Dept; 2 (225–253). WAM P–uncat.; N. of North Point, Rottnest Is., off Perth; Jan. 17, 1961; 2 (57.7–95.2). SMN 2623 + 2693; W.A.; Müller; 3 (215–270).

"Australia", 6 specimens (136–252 mm) from 4 collections: MCZ 46720; Müller; 2 (136–163). MNHN 1905; Müller; 1 (205). MNHN A.7635; Emeric; 1 (136). SMN 3367; Müller; 2 (234–252).

Hyporhamphus ihi Phillipps

New Zealand Garfish or Piper

Figs 16–17, Tables 5–6

Hemirhamphus intermedius.—Günther, 1866: 260–1 (description in part, New Zealand [BMNH 1855.9.19.1064]). Klunzinger, 1880: 414 (in part, New Zealand [SMN 3687]). Hutton, 1889: 283 (listed). Ogilby, 1893: 172–3 (in part). Gill, 1893: 103, 114 (listed, previous records). Hutton, 1904: 50 (listed). Stead, 1906: 66–7 (in part, N.Z. included in range). Phillipps, 1927a: 21 (previous N.Z. records). Phillipps, 1927b: 12 (food fish in N.Z.). Thomson, 1931: 31 (worms and small crustaceans in stomachs). Benham, 1938: 36 (cold July killed most garfish in outside ponds, Portobello, N.Z.), 37 (gravid females, Feb. and March). Graham, 1938: 404 (abundant on *Zostera* flats in Otago Harbour, N.Z.; 400–1,000 doz. per seine haul; reaches 26 in., mean 16 in.). Graham, 1939a: 424 (three species of predators, Otago Harbour, N.Z.), 435 (herbivores, feeding primarily on *Zostera* and *Ulva*). Graham, 1939b: 364 (eggs and development), pl. 42, figs 1–11 (development). Baylis, 1944: 469–471 (*Micracanthocephalus hemirhamphi*, a new species of acanthocephalan from garfish stomach; Otago Harbour). Powell, 1947: 66 (common in estuaries of N. and S. islands; excellent food fish; methods of capture), fig. 312. Graham, 1953: 157–161 (eggs and embryos), fig. of *Hy. australis* after Roughley, 160 (development figs after Graham, 1939b). (Not *Hemiramphus intermedius* Cantor, 1842.)

Hemiramphus intermedius.—Hector, 1872: 118 (common, N.Z.; highly appreciated food fish; methods of capture), pl. 9, fig. 86. Hutton, 1872: 53–4 (description; abundant at Wellington and Auckland; range in part). Sherrin, 1886: 33–5 (description; food value), 284 (size limit—9 in.), 305 (listed). Phillipps, 1921: 120 (abundant, northern N.Z.), 125 (sold in Wellington markets on 37 days, March–Aug., 1918). Phillipps and Hodgkinson, 1922: 94 (Auckland market, June and July only). Thomson, 1932: 26 (ripe in Nov. and Dec. at Portobello; hatching after 44 days; growth of lower jaw), figs. Fowler, 1940: 757 (N.Z. specimen [USNM 83332]; Wilkes Exped. 1838–1842). Morrow, 1952: 144 (favorite food of striped marlin; records interpreted by Baker, 1966 as being *Scomberesox saurus*), 145 (1 spec. in stomachs of 38 *Makaira mitsukurii*). Baker, 1966: 820 (Morrow's 1952 report of "piper" interpreted as *Scomberesox saurus*).

Hyporhamphus intermedius.—Waite, 1907: 15 (listed, N.Z.). Phillipps, 1918: 271 (large numbers caught yearly near Picton for shipment to Wellington). Thomson and Anderton, 1921: 72 (common spring and summer, Otago Harbour; ripe in Jan.; description of eggs).

Hyporhamphus ihi Phillipps, 1932: 230 (original description; Wellington, N.Z.; comparison with Australian *Hy.* "*intermedius*"—*Hy. australis* and *Hy. melanochir* combined).

Reporhamphus ihi.—Graham, 1956: 157–161 (description; development from Graham, 1939b), 240 (part of main diet of *Arripis trutta*), 363 (in stomachs of *Currupiscis kumu*). Doogue and Moreland, 1960: 195 (fig., description, habits, predators, fishing methods). Doogue and Moreland, 1961: 206 (after 1960 with notes on food quality added). Whitley, 1968a: 36 (listed). Russell, 1969: 108 (surface species, Goat Is., N. of Auckland). Stephenson, 1969: 427 (cymothoid isopod *Irona melanosticta* common on specimens from Bay of Islands and Hauraki Gulf). Grace, 1971: 132, 135 (Whangateau Harbour, surface schooling fish). Hewitt and Hine, 1972: 94 (list of parasite records).

Hemiramphus australis.—Moreland, 1957: 34 (Chatham Is. [DM 4534], new record). (Not *Hemiramphus australis* Steindachner, 1866.)

Diagnosis

Hy. ihi differs from *Hy. australis* and resembles *Hy. melanochir* in having fewer gill-rakers (Table 5), usually 32 or less on the first arch (compared to 34 or more) and 25 or less on the second arch (usually 27 or more). *Hy. ihi* has a relatively longer upper jaw (usually longer than wide) and lower jaw (usually longer than head length) than do either *Hy. australis* or *Hy. melanochir*, especially at larger sizes (Figs 16 and 17). The pelvic fins are placed further anterior in *Hy. ihi:* the P_2–C distance usually falls on the opercle or on the pectoral fin base instead of on the adpressed pectoral fin as in both *Hy. australis* and *Hy. melanochir.*

Description

Upper jaw long and pointed, usually longer than wide (34 of 44 specimens, Fig. 16); width divided by length 0.82–1.08, $\bar{x}$ 0.94. Regression of upper jaw length on standard length significantly different from both *Hy. australis* and *Hy. melanochir;* regression of upper jaw width significantly different from *Hy. melanochir* (Table 6). Lower jaw length moderate, slightly longer than head length (Fig. 17); head length divided by lower jaw length 0.57–1.01, $\bar{x}$ 0.76 over entire size range. Pelvic fins placed slightly anterior to midway between pectoral fin origin and caudal fin base; P_2–C distance divided by P_1–P_2 0.83–1.11, $\bar{x}$ 0.98; P_2–C extension falls on opercle to mid-adpressed pectoral fin, usually on opercle or pectoral fin base. Dorsal rays 15–18, usually 16; anal rays 17–20, usually 18; pectoral rays 11 or 12. Vertebrae (36–38) + (18–21) = 55–58, usually 37 + 19 = 56. Gill-rakers similar to the Victorian population of *Hy. melanochir*, 27–33 on first arch, usually 28–30; 21–25 on second arch, usually 22–24. Dorsal fin base about as long as anal fin base; dorsal base divided by anal base 0.95–1.09, $\bar{x}$ 1.03; regression of anal fin base on standard length significantly different from both *Hy. australis* and *Hy. melanochir* (Table 6).

Maximum size

Hy. ihi is apparently a smaller species than either of the Australian species of sea garfishes, reaching only 260 mm SL (male, BMNH 1886.11.18.91, Dunedin).

Types

No types are extant and Phillipps apparently did not designate any (J. Moreland, pers. comm.).

Discussion

In the original description of *Hy. ihi*, Phillipps (1932) claimed that the chief differentiating character between *Hy. ihi* and the Australian sea garfish *Hy.* "*intermedius*" (presumably *Hy. australis* and *Hy. melanochir* combined) was that the lower jaw was distinctly longer than the head in *ihi* and approximately equal in "*intermedius*". As Fig. 17 shows, the lower jaw in all three species is distinctly longer than the head at smaller sizes (up to about 200 mm SL). *Hy. australis* and *Hy. ihi* do, however, appear to have a slightly longer lower jaw than does *Hy. melanochir* but it is not statistically significant (Table 6). *Hy. ihi* is obviously the New Zealand representative of the Australian sea garfishes and is here accorded specific rank because of its more anteriorly placed pelvic fins and because *Hy. australis* and *Hy. melanochir* are considered species. The three species make up one zoogeographical species or superspecies.

Table 7. Comparison of regression equations and F values for slopes and heights of eight morphometric characters for four populations of *Hy. melanochir* (= Significant at 99.9% level)**

Character	Regression equations Y =				F values					
	Tasmania	Victoria	S. Australia	W. Australia	Tasmania vs. Victoria		Victoria vs. S. Australia		S. Australia vs. W. Australia	
					Slopes	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*
Lower jaw length	0.1658X + 13.056	0.1558X + 13.475	0.1558X + 10.577	0.1625X + 10.323	0.465	1.59	−0.001	13.30**	0.346	1.34
Head length	0.2141X − 2.040	0.1992X + 0.754	0.2110X − 0.558	0.2166X − 1.002	9.59	3.06	10.03	7.58	1.99	3.60
P_1–P_2	0.4223X − 1.700	0.4170X − 1.472	0.4298X − 2.165	0.4263X − 1.929	0.266	0.914	2.51	7.02	0.336	0.661
P_2–C	0.3664X + 2.294	0.3761X + 0.844	0.3592X + 2.281	0.3628X + 1.966	1.62	0.225	8.81	12.81**	0.379	0.609
Base dorsal fin	0.1323X + 1.825	0.1364X + 1.525	0.1369X + 1.404	0.1324X + 1.896	0.915	1.18	0.021	−0.033	3.09	2.63
Base anal fin	0.1219X + 2.372	0.1252X + 2.336	0.1196X + 2.794	0.1200X + 2.607	0.472	2.16	1.66	2.70	0.012	0.133
Upper jaw length	0.0426X − 0.218	0.0385X + 0.176	0.0442X − 0.260	0.0461X − 0.460	3.16	2.59	6.32	11.13	1.27	1.36
Upper jaw width	0.0515X − 1.279	0.0500X − 0.606	0.0540X − 0.940	0.0557X − 1.185	0.358	9.21	3.88	6.29	0.694	0.180
Degrees of freedom					1, 37–59		1, 50–61		1, 70–76	

Distribution

Restricted to New Zealand and the Chatham Islands.

Material

112 specimens (53.4–260 mm SL) from 27 collections arranged from north to south.

New Zealand: BMNH 1855.9.19.79; North Is., Bay of Islands; Haslar Coll.; 3 (111–188). ANSP 117424; Bay of Islands, E. side Urupukapuka I.; W.A. Starck II and J. Moreland; WAS NZ–17; Feb. 29, 1960; 6 (83.5–189). ANSP 117423; Bay of Islands, N.W. of Urupukapuka I.; W.A. Starck II and J. Moreland; WAS NZ 11 + 12; Feb. 25, 1960; 1 (170). SMF 2304; Hauraki Gulf; H. Suter; 1908; 1 (202) and SMF 2471; same data; 1 (211). USNM 205745; Port Charles, 36° 32′ S.; Feb. 28, 1957; 5 (57.2–97.7); and DM 2291; same data 6 (70.2–87.5). SMN 3687; Auckland; Kramer; 1 (140). SU 15835; Auckland Harbour; Hubbs et al.; Feb. 1949; 2 (123–129). USNM 177041; near Auckland; J. Howard; Jan. 6–Feb. 1, 1953; 2 (81.7–139) and USNM 177062; same data; 4 (194–236). USNM 205747; Raumati Beach, 40° 55′ S.; D. M. Patchett; Feb. 15, 1968; orig. DM 4865; 6 (179–193). BMNH 1873.12.13.48–9; Wellington Harbour; 2 (205–219). DM 4335; Wellington Harbour; 2 (203–221). ZMUC 341790–811; Wellington; Galathea 627; Jan. 23–24, 1952; 22 (76.1–197). CSIRO C.2043; Cook Straits; 1947–48; 1 (187). DM 4766; Port Ligar, Pelorus Sound; May 27, 1966; 2 (54.0–56.8). USNM 205743; Queen Charlotte Sound; J. Moreland; Sept. 1, 1951; 5 (53.4–87.1); DM 933; same data; 7 (56.6–76.4); and CSIRO; same data; 8 (70.5–132). BMNH 1913.12.4.4; Lyttelton Harbour; "Terra Nova"; 1 (187). DM 3606; Islington Bay, Lyttelton Harbour; Feb. 16, 1962; 2 (140–149). BMNH 1886.11.18.91; Dunedin; Otago Mus.; 1 (260). ANSP 101740; Otago coast; 5 (227–255). USNM 205744; Dunedin Harbour; J. Moreland; Jan. 21, 1957; 2 (109–114); and DM 2157; same data; 2 (88.5–113). MNHN B.1037; Nouvelle Zelande; Hast; 1 (247). NHMV uncat.; New Seeland; Reischek; 1881; 2 (147–194). BMNH 1855.9.19.1064; New Zealand; Haslar Coll.; 3 (126–200). USNM 39692; New Zealand; 1888; Otago Mus.; 1 (258). USNM 83332; New Zealand; Wilkes Exped.; 1 (250).

Chatham Islands: USNM 205746; Te Whanga Lagoon, 44° S., 176° 30′ W.; Oct. 25, 1965; 2 (66.6–74.5); and DM 4534; same data; 2 (54.8–59.7).

Hyporhamphus quoyi (Valenciennes)

Short-nosed Garfish

Fig. 18, Tables 8–9

Hemiramphus Quoyi Valenciennes *in* Cuvier and Valenciennes, 1846: 35–6 (original description; Port Dourey, New Guinea). Whitley, 1928: 214–5 (synonymy; records from Qld., Gulf of Carpentaria, and Darwin [AMS I.1523], N.T.). McCulloch, 1929: 102 (listed; Qld., N. Australia). Anon., 1945: 8 (listed among Cairns, Qld. marketable fishes). Whitley, 1947: 149 (Dampier Arch. and Exmouth Gulf, new W.A. records). Roughley, 1951: 23 (Qld. and W.A., no N.S.W. records). Ogilby, 1954: 9 (common in Moreton Bay and Brisbane R., Qld.; ascends rivers to end of tidal influence; good food fish), fig. 7. Marshall *et. al.* 1959: 27 (description; Qld.), fig. (after Paradice and Whitley, 1927). Marshall, 1964: 99 (description; Qld.; food fish), pl. 24, fig. 107. Marshall, 1966: 174 (shortened from Marshall, 1964), pl. 24, fig. 107.

Hemiramphus Gaimardi Valenciennes *in* Cuvier and Valenciennes, 1846: 36–7 (original description; in part, specimens from New Guinea and Amboina).

Hemiramphus melanurus Valenciennes *in* Cuvier and Valenciennes, 1846: 42–3 (original description; Celebes Islands).

Hemirhamphus quoyi(i).—Schmeltz, 1879: 57 (Bowen, Qld.). Günther, 1880: 50 (Somerset, Cape York [BMNH 1879.5.14.474], Qld.). Kent, 1889: 240 (Port Darwin District). Cockerell, 1913: 51–2 (scale characters, Qld. specimens). McCulloch and Whitley, 1925: 138 (previous Qld. records). Paradice and Whitley, 1927: 80 (Pellew Is., Gulf of Carpentaria [AMS IA.1681–4]; fairly common), pl. 11, fig. 2. Grant, 1965: 37 (description after Munro, 1957; ocean beach estuaries and saline estuaries of entire Qld. coast; reaches 14 in., good food fish), fig. Grant, 1972: 62 (description after Munro, 1967; text after Grant, 1965).

Belone quoyi.—Kluzinger, 1880: 415 (syncnymy; description; Port Darwin and Endeavour R. [SMN 2603, 2435]).

Tylosurus quoyi.—McCulloch and Whitley, 1925: 138 (based on Klunzinger, 1880).

Reporhamphus quoyi.—Whitley, 1948: 15 (listed, between North West Cape and 80-mile Beach, W.A.).

Reporhamphus caudalis Whitley, 1951: 393 (original description; Cape York, Qld.). Whitley, 1964b: 38 (listed).

Hyporhamphus quoyi.—Taylor, 1964: 105 (Arnhem Land [11 USNM collections], N.T.; description). Whitley, 1964b: 39 (listed).

Hemirhamphus caudalis.—Grant, 1972: 67 (brief description).

Misidentification:

Hemiramphus limbatus.—Borodin, 1932: 73 (Brisbane, Qld. [VMM 899]).

Diagnosis

A species of *Hyporhamphus* with a very short lower jaw, equal to the head length at about 100 mm SL, gradually decreasing to half the length of the head in adults. *Arrhamphus sclerolepis* has almost no lower jaw at all; all other Australian garfishes have a longer lower jaw. Upper jaw broadly rounded, much wider than long. Preorbital canal with a wide short posterior branch opening in a larger pore than other Australian garfishes (Fig. 2, l–n); ventral pore about as large as in *Hy. affinis* and *Hy. dussumieri* (Fig. 2, h–k).

Description

Upper jaw width divided by length 1.27–2.30, means for the five populations 1.69–1.83, overall mean 1.75. Dorsal rays 15–17, usually 16; anal rays 14–16, usually 15 or 16; pectoral rays usually 12, occasionally 11 or 13. Vertebrae (36–39) + (16–18) = 52–56. Gill-rakers on first arch (9–14) + (19–25) = 27–39; on second arch (4–7) + (18–25) = 22–31; counts increasing from Queensland westward (Table 8). Pelvic fins inserted closer to pectoral origin than to caudal base; P_2–C distance divided by P_1–P_2 0.96–1.25, population means 1.03–1.12, overall mean 1.08; P_2–C extension falls on preopercle, opercle, or between opercle and pectoral fin base, usually on the middle of the opercle. Dorsal fin base longer than anal fin base; dorsal base divided by anal 1.09–1.40, population means 1.26–1.30, overall mean 1.28. Maximum body depth greater than maximum body width.

Maximum known size

312 mm SL (AMS I.13243, Shark Bay, W.A.).

Table 8. Number of fin rays, gill-rakers, and vertebrae in populations of *Hyporhamphus quoyi* from Australia and New Guinea. ([1]/holotype of *Reporhamphus caudalis* Whitley; [2]/holotype of *Hemiramphus quoyi* Valenciennes)

Population	Dorsal					Anal					Pectoral		
	15	16	17	N	$\bar{x}$	14	15	16	N	$\bar{x}$	11	12	13
N.S.W.–SE. Queensland	9	27	2	38	15.82	1	18	19	38	15.47	1	25	1
NE. Queensland	3	19[1]	8	30	16.17	..	16[1]	14	30	15.47	..	13[1]	2
Gulf of Carpentaria	1	32	12	45	16.24	1	31	13	45	15.27	..	18	7
N. Territory	2	10	1	13	15.92	..	12	1	13	15.08	..	12	..
W. Australia	5	27	8	40	16.08	2	19	19	40	15.40	..	12	5
New Guinea	4	39[2]	8	51	16.08	3[2]	38	10	51	15.14	6[2]	31	3

Population	First Arch Gill-rakers														
	27	28	29	30	31	32	33	34	35	36	37	38	39	N	$\bar{x}$
N.S.W.–SE. Queensland	..	4	9	9	9	3	..	..	..	..	..	..	..	34	29.94
NE. Queensland	..	..	..	2	9	6[1]	9	1	..	..	..	..	..	27	31.93
Gulf of Carpentaria	..	..	..	..	5	13	16	16	10	2	..	..	..	62	33.31
N. Territory	..	..	..	..	..	..	2	4	4	2	..	..	..	12	34.50
W. Australia	..	..	..	..	..	4	6	7	11	6	3	..	1	38	34.61
New Guinea	1	4	9	14	12[2]	4	3	..	1	..	..	..	..	48	30.29

Population	Second Arch Gill-rakers											
	22	23	24	25	26	27	28	29	30	31	N	$\bar{x}$
N.S.W.–SE. Queensland	5	10	11	7	1	..	..	..	..	..	34	23.68
NE. Queensland	..	..	6	2	12	4[1]	2	..	..	..	26	25.77
Gulf of Carpentaria	..	..	3	11	13	17	14	4	..	..	62	26.65
N. Territory	..	..	..	..	..	2	6	4	..	..	12	28.17
W. Australia	..	..	..	1	3	9	8	9	8	1	39	28.26
New Guinea	1	8	14[2]	13	7	5	..	..	..	..	48	24.67

Population	Vertebrae						
	52	53	54	55	56	N	$\bar{x}$
SE. Queensland	..	..	1	4	..	5	54.80
NE. Queensland	..	1	1	1[1]	1	4	54.50
Gulf of Carpentaria	..	13	20	4	..	37	53.76
N. Territory	..	1	7	..	..	8	53.88
W. Australia	..	..	2	21	7	30	55.17
New Guinea	10	8	1	..	..	19	52.53

Types

Hemiramphus quoyi Valenciennes, 1846. Holotype MNHN B.1068; New Guinea; Quoy and Gaimard; 1 (212). Lower jaw length 28.6 mm; head length 53.5 mm; P_1–P_2 79 mm; P_2–C 80.5 mm; P_2—C extension falls on posterior third of opercle; D 16; A 14; P_1 11–11; RGR_1 10 + 21 = 31; RGR_2 5 + 19 = 24. Preorbital canal shown in Fig. 2l.

Hemiramphus melanurus Valenciennes, 1846. Holotype MNHN B.1057; Celebes; Quoy and Gaimard; female (183). Lower jaw length 26.0 mm; head length 39.4 mm; P_1–P_2 69.2 mm; P_2–C 78.2 mm; P_2–C extension falls on anterior third of opercle; D 15; A 15; P_1 11–11; RGR_1 11 + 22 = 33; RGR_2 4 + 18 = 22.

Hemiramphus gaimardi Valenciennes, 1846. Lectotype MNHN B.1058; New Guinea; 166 mm; herein selected because it best fits Valenciennes' original description. Lower jaw length 25.3 mm; head length 36.4 mm; P_1–P_2 60.0 mm; P_2–C 70.8 mm; P_2–C extension falls on preopercle-opercle margin; D 16; A 15; P_1 11–11; RGR_1 9 + 19 = 28; RGR_2 4 + 19 = 23. Paralectotypes MNHN B.1058, New Guinea, 1 (152); and MNHN 4591, Amboina, 1 (151). Preorbital canal of paralectotype B.1058 shown in Fig. 2m.

Reporhamphus caudalis Whitley, 1931. Holotype AMS I.444; Cape York, Queensland; exch. Qld. Mus., May 1886; 1 (94.3). Paratype same number and data; 1 (90.9). Data for holotype (paratype in parentheses). Lower jaw length 22.1 mm (25.3); head length 20.5 mm (19.2); P_1–P_2 35.8 mm (33.5); P_2–C 37.1 mm (36.2); P_2–C extension falls on posterior margin of opercle in both; D 16 (17); A 15 (15); P_1 12–12 (?–12); RGR_1 10 + 22 = 32 (11 + 21 = 32); RGR_2 5 + 22 = 27 (4 + 20 = 24); total vertebrae 55 (54). Preorbital canal shown in Fig. 2n.

Geographic variation

The Australian material was divided into five geographic areas for comparisons: New South Wales—SE. Queensland (north to Maryborough); NE. Queensland (from the Cumberland Group off MacKay north); Gulf of Carpentaria; Northern Territory; and Western Australia. Meristic data for these five populations (and New Guinea) are compared in Table 8. There is an increasing cline in number of gill-rakers on both the first and second gill-arches from Queensland to the Northern Territory to Western Australia. The New Guinea population is most similar to SE. Queensland. There are also geographic differences in vertebral number. The northern populations clearly have fewer vertebrae than the Western Australian population and probably fewer than in SE. Queensland but that sample is inadequate. The New Guinea population has still fewer vertebrae. There are no significant differences between the populations in the numbers of fin-rays, the Australian and New Guinea populations usually having 16 dorsal, 15 anal, and 12 pectoral rays.

There are also significant morphometric differences among some cf the five Australian populations of *Hy. quoyi* in six of eight characters (Table 9). The New South Wales-SE. Queensland population differs significantly from the NE. Queensland population in the heights of regression lines for three characters: lower jaw length, head length, and P_1–P_2 distance. The NE. Queensland population also differs from the Gulf of Carpentaria population in lower jaw length but not in the other two characters. Combining the Gulf of Carpentaria with the Northern Territory and Western Australian populations showed the western group still significantly different in lower jaw length from NE. Queensland (F for heights 11.69**). For both head length and P_1–P_2 distance, NE. Queensland was combined with the western three populations and compared with N.S.W.-SE. Queensland. This test showed no

Table 9. Comparison of regression equations and F values for slopes and heights of eight morphometric characters for five Australian populations of *Hy. quoyi* (= Significant at 99.9% level)**

Character	Regression equations Y =				
	SE. Queensland	NE. Queensland	Gulf of Carpentaria	Northern Territory	Western Australia
Lower jaw length	0.0631X + 18.386	0.0434X + 18.721	0.0593X + 13.96	0.0420X + 17.80	0.0430X + 17.449
Head length	0.2182X − 0.344	0.2182X + 0.514	0.2204X + 0.705	0.2244X + 0.458	0.1837X + 4.768
P_1–P_2	0.3973X − 1.340	0.3908X − 1.978	0.3780X − 1.627	0.3270X + 6.203	0.3875X − 0.955
P_2–C	0.4100X − 1.446	0.4115X − 0.628	0.4276X − 2.078	0.4337X − 3.079	0.4114X − 1.458
Base dorsal fin	0.1522X − 0.273	0.1511X + 0.461	0.1550X + 0.069	0.1569X − 0.310	0.1539X − 0.156
Base anal fin	0.1084X + 0.962	0.1118X + 1.184	0.1197X + 0.096	0.1125X + 0.913	0.1122X + 0.865
Upper jaw length	0.0334X − 0.208	0.0297X + 0.336	0.0266X + 0.437	0.0363X − 0.523	0.0277X + 0.694
Upper jaw width	0.0561X − 0.282	0.0568X − 0.206	0.0591X − 0.399	0.0807X − 3.353	0.0557X + 0.164

Character	F values							
	SE. Queensland vs. NE. Queensland		NE. Queensland vs. Gulf of Carpentaria		Gulf of Carpentaria vs. Northern Territory		Northern Territory vs. Western Australia	
	Slopes	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*	*Slopes*	*Heights*
Lower jaw length	3.32	14.62**	1.52	17.49**	0.422	6.16	0.001	0.085
Head length	−0.089	14.98**	0.199	4.78	0.160	0.195	0.657	2.31
P_1–P_2	1.00	15.75**	2.37	11.44	9.98	0.644	9.42	13.10**
P_2–C	0.007	6.24	4.00	2.86	0.152	−0.160	1.30	14.88**
Base dorsal fin	0.043	4.47	0.791	0.062	0.059	−0.032	0.041	1.21
Base anal fin	0.851	9.17	3.97	−0.091	0.860	1.69	−0.041	0.345
Upper jaw length	3.42	−0.011	1.94	9.55	2.87	27.38**	1.42	0.331
Upper jaw width	0.130	2.28	1.31	1.98	12.37**	5.68	14.84**	4.26
Degrees of freedom	1, 47–49		1, 64–66		1, 53–54		1, 41–46	

significant differences for head length (F for heights 11.13) but it was significant for P_1–P_2 distance (F for heights 36.54**). For P_2–C distance, the Western Australia population is significantly different from the Northern Territory (F for heights 14.88**) but not from the combined four eastern populations (F for heights 10.97). The Gulf of Carpentaria population is significantly different from the Northern Territory in both upper jaw length and width (Table 9), and it is also significantly different when tested against the combined Northern Territory and Western Australia groups in upper jaw length (F for heights 19.32**). For upper jaw width, the Northern Territory is also significantly different from Western Australia. There are no significant differences between any of the populations in either the length of the dorsal or anal fin bases.

The geographic variation in *Hy. quoyi* shows some similarities to that found in *Arrhamphus sclerolepis*. It differs in that the number of gill-rakers shows a sharper division along the middle of the eastern Queensland coast in *Arrhamphus* than in *Hy. quoyi*. The differences in vertebral number divide *Arrhamphus* into two subspecies whereas the differences in *Hy. quoyi* show latitudinal correlations that may indicate that vertebral number in this species is temperature dependent. Final evaluation of the geographic variation in *Hy. quoyi* must await completion of variational studies throughout the range of the species.

Distribution

A tropical species whose range is centered around the East Indies, Philippine Islands, and Australia. In Australia, found from Yamba Bay, Clarence River, N.S.W. (CSIRO uncat. juvenile) north along the Queensland coast, around Cape York, throughout the Gulf of Carpentaria, and along the southern coast of the Timor Sea into the Indian Ocean south to Shark Bay, Western Australia (Fig. 18).

Australian Material

223 specimens (27.2–312 mm SL) from 60 collections arranged from south to north along the east coast and then from east to west along the north coast of Australia.

New South Wales: CSIRO; Clarence R., Yamba Bay; May 20, 1946; 1 (67.6).

Queensland, 87 specimens (27.2–295 mm) from 29 collections: VMM 899; Brisbane; W. K. Vanderbilt, "Alva"; 1931–32; 2 (268). MCZ 33018; Brisbane; W. K. Vanderbilt; 1932; 1 (295). SU 13039; Brisbane R., J. D. Ogilby; 1 (267). CSIRO; Moreton Bay; May 1, 1945; 1 (35.0). CSIRO; N. end Bribie Is. Cr.; Jan. 22, 1945; 2 (77.0–90.0). CSIRO; Bribie Is. Banks, Caloundra; May 1944; 2 (59.3–73.3). CSIRO; Noosa R. near entrance; April 22, 1944; 9 (53.0–106). CSIRO; Noosa R. at Tewantin; Sept. 24, 1945; 1 (83.1). CSIRO; Noosa R. near Tewantin buoys; July 16, 1944; 7 (74.3–90.8). CSIRO; Noosa R.; 1944; 4 (84.2–111). CSIRO; The Bluff, S. Fraser Is. off Maryborough; Aug. 24, 1950; 4 (68.3–79.5). AMS IA.1680; St Bees Is., Cumberland Group; W. E. J. Paradice, HMAS "Geranium"; Dec. 1923; 1 (204). AMS IA.6726, 6728; Lindeman Is., Cumberland Group; G. P. Whitley; 2 (202–231) + 2 heads. AMS IA.6111–2; Hayman Is., Cumberland Group; Embury; 2 (215–227). AMS IA.6122–5; Hayman Is., Cumberland Group; Embury; 6 (36.9–111). AMS IA.2308–11; Cumberland Group; W. E. J. Paradice, HMAS "Geranium"; Oct. 1924; 4 (139–161). BMNH 1871.9.13.116; Pt Bowen; purch. from Schmeltz; 1 (121). AMS IB.1487; Magnetic Is. off Townsville; G. Coates; Aug. 1, 1945; 1 (277). MCZ 38536; Turtle Bay, near Cairns; E. J. Coulter; June 16, 1953; 1 (174). AMS I.14505; Walker Bay near Cooktown; A. R. McCulloch; Aug. 1918: 1 (165). SMN 2435 + 2603; Endeavour R., Cooktown; Müller; 2 (215–221). USNM 176835, 176893; "Great Barrier Reef"; J. Howard; April 8–May 29, 1953; 7 (168–243). CSIRO; Marrett R., Princess Charlotte Bay; M/V "Australia"; Sept. 27, 1948; 8 (56.9–91.6). CSIRO; Little N. Marrett R.; Sept. 27, 1948; 2 (27.2–41.0). AMS I.11814; Murray Is., Torres Strait; Hedley and McCulloch; Aug.–Oct. 1907; 1 (129). ANSP 82304; Darnley Is., Torres Strait; orig. QM I.1078; 1 (218). AMS I.444; Cape York; exch. Qld Mus.; May 1886; types of *Reporhamphus caudalis* Whitley; 2 (90.9–94.3). BMNH 1879.5.14.474; Somerset, Cape York; "Challenger"; 2 (236–250). AMS IB.6888–9; Inscription Point, Sweers Is., South Wellesley Is., Gulf of Carpentaria; D. McMichael and J. Yaldwyn; 3 (78.5–101). USNM 206579; "Queensland", prob. S.E. Qld; purch. Sydney fish mkt.; BBC–1466; April 8, 1970; 5 (201–252).

Northern Territory, 94 specimens (38.7–216 mm) from 17 collections: AMS IA.1681–4; Sir Edward Pellew Group, Gulf of Carpentaria; W. E. J. Paradice, HMAS "Geranium"; Dec. 1923; 6 (131–216). ANSP 86430; Pellew Group; orig. QM I.3973; 1 (140). USNM 173783; Emerald R., Groote Eylandt; R. R. Miller 48–15; June 3–5, 1948; 4 (111–149). AMS I.16155; Thompson Bay, S. end Port Langdon, Groote Eylandt; R. R. Miller 48–10; May 1, 1948; 3 (94.2–125). USNM 173785; Little Lagoon, 2 miles E. Umbakumba, Groote Eylandt; R. R. Miller 48–19; June 26, 1948; 3 (88.7–118). USNM 173784; Bartalumba Bay, Groote Eylandt; R. R. Miller 48–17; June 7, 1948; 2 (110–115). USNM 173782; S. end Winchelsea Is. off N. coast Groote Eylandt; R. R. Miller 48–13a; June 6, 1948; 2 (93.4–110). USNM 173781; Bickerton Is. N.W. of Groote Eylandt; R. R. Miller 48–13; June 2, 1948; 2 (72.1–76.7). USNM 173787; Port Bradshaw S. of Cape Arnhem; R. R. Miller 48–24; July 26, 1948; 22 (77.8–158); and AMS I.16154; 10. USNM 173788; Port Bradshaw S. of Cape Arnhem; R. R. Miller 48–25; July 23, 1948; 20 (81.5–121). USNM 173789; Port Bradshaw S. of Cape Arnhem; R. R. Miller 48–28; July 25, 1948; 4 (94.2–125). USNM 173786; Yirrkalla, N. of Cape Arnhem; R. R. Miller 48–21; July 29–Aug. 11, 1948; 2 (135–146). CSIRO; off Black Point, Port Essington, Cobourg Peninsula; Oct. 3, 1949; 1 (38.7). USNM 173779; Nightcliff, 7 mi. N. of Darwin; R. R. Miller 48–2; March 19–25, 1948; 8 (101–183). CSIRO C. 1724; Darwin; 1 (133). AMS I.1523; Darwin; W. E. J. Paradice, HMAS "Geranium"; Aug. 1923; 1 (145). AMS IA.7750–1; Darwin; M. Ward; 2 (146–150).

Western Australia, 40 specimens (36.3–312 mm) from 12 collections: AMS I.15224; Cockatoo Is., Buccaneer Archipelago; June 1911; 1 (255). WAM P–13302; Cockatoo Is., Buccaneer Archipelago; G. A. Robinson; 1911; 1 (146). AMNH 40009; Cape Bossut; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–78; April 16, 1969; 2 (160–170). AMS I.13240–2; Port Hedland; W.A. Fish. Dept; Aug. 1914; 3 (200–235). WAM P–19106; Port Hedland; A. Kalnins; May 31, 1965; 1 (144). AMS IB.2642; Depuch Is.; CSIRO; 1 (217). AMNH 40007; S. of Mandu Mandu Cr., North West Cape; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–59; April 4, 1969; 7 (112–153). AMNH 40001.; S. of Mandu Mandu Cr., North West Cape; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–57; April 3, 1969; 4 (118–128). AMNH 40006; 5 mi. S. Yardi Station, North West Cape; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–55; April 2, 1969; 17 (69.5–124). AMS I.13243; Shark Bay; W.A. Fish. Dept; Aug. 1914; 1 (312). AMS IB.1642; Cape Peron, Shark Bay; CSIRO; 1 (118). WAM P–uncat.; Shark Bay; R. J. McKay; March 2, 1962; 1 (36.3).

Hyporhamphus affinis (Günther)

Fig. 19

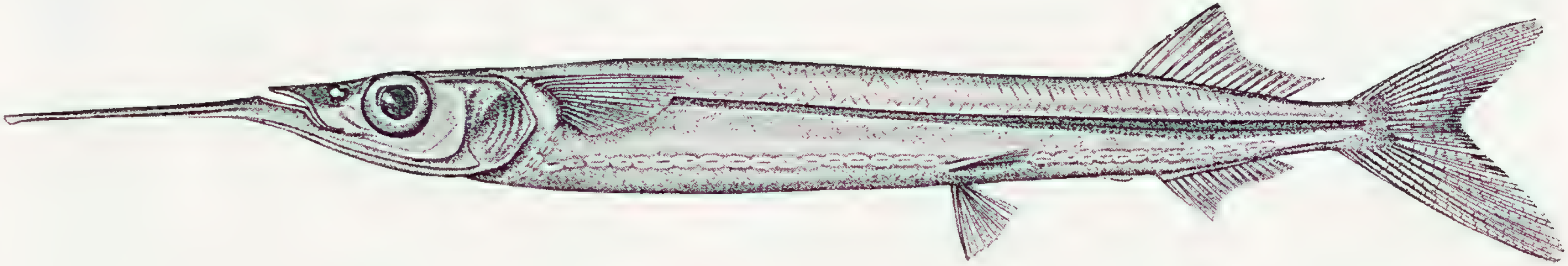
Hemirhamphus affinis Günther, 1866: 267 (original description; "South Seas").

Diagnosis

Generally similar to *Hy. dussumieri* but different in having fewer gill-rakers on the first arch (35 or fewer vs. 36 or more), lacking the prominent line of pigment along the ventral part of the lateral line, having the body depth distinctly greater than body width, and having the preorbital distance greater than the upper jaw length. In this last character, *Hy. affinis* is similar to *Hy. balinensis* (Bleeker) of New Guinea and the East Indies but the preorbital distance is only 1.03–1.35 ($\bar{x}$ 1.19) times the upper jaw length in *Hy. affinis* compared to nearly twice as long in *Hy. balinensis*.

Description

Posterior branch of preorbital canal present; additional pores frequently present, usually one at junction of posterior and ventral branches, and one at junction of dorsal and ventral branches (Fig. 2, h–i). Lower jaw about equal to head length; head length divided by lower jaw length 0.82–1.24, $\bar{x}$ 0.95. Dorsal rays 15 or 16, rarely 17; anal rays 15–17, rarely 18 in Australian specimens (up to 19 elsewhere); pectoral rays 11 or 12, rarely 13. Vertebrae (38–40) + (16–18) = 55–57. Gill-rakers on first arch (8–10) + (20–26) = 28–35 in Australian specimens, 30–38



Above.—Figure 19. *Hyporhamphus affinis*, AMNH DER 69-51, 105 mm SL, Bush Bay S. of Carnarvon, W.A. *Below.*—Figure 20. *Hyporhamphus dussumieri*, USNM 206575, 230 mm SL, One Tree Is., Great Barrier Reef, Qld.

elsewhere, on second arch (3–6) + (18–23) = 22–28 in Australian specimens, 20–27 elsewhere. Pelvic fins located midway between pectoral fin origin and caudal base; P_1–P_2 distance equal to P_2–C distance; P_2–C distance divided by P_1–P_2 0.94–1.09, $\bar{x}$ 1.01; P_2–C extension reaches from posterior third of opercle to pectoral fin base. Dorsal fin base longer than anal fin base; dorsal base divided by anal base 1.06–1.33, $\bar{x}$ 1.20. Preorbital distance slightly greater than upper jaw length; preorbital distance divided by upper jaw length 1.04–1.35, $\bar{x}$ 1.19. Preorbital distance shorter than orbit; orbit divided by preorbital distance 1.13–1.82, $\bar{x}$ 1.48. Width of upper jaw distinctly greater than length; width divided by length 1.04–1.76, $\bar{x}$ 1.49.

Maximum known size

243 mm SL (Gilbert Islands), 151 mm in Australia (CSIRO C.1732, Timor Sea).

Lectotype

BMNH pre-reg.; "South Seas"; 1 (100); herein selected because it is the larger syntype and it is in the better condition. Lower jaw length 29.1 mm; head length 21.0 mm; P_1–P_2 41.3 mm; P_2–C 35.5 mm; P_2–C extension nearly reaches posterior end of adpressed pectoral fin; D 16; A 16; P_1 12–12; RGR_1 9 + 24 = 33; RGR_2 4 + 20 = 24; preorbital canal with posterior branch and two pores in middle of canal (Fig. 2h). Paralectotype BMNH pre-reg.; "South Seas"; 1 (82.0).

Distribution

A wide-spread and poorly studied tropical species known from the East Indies to the South Pacific. In Australia, known only from the Timor Sea, Northern Territory and Western Australia.

Australian Material

16 specimens (48.2–151 mm SL) from 6 collections.

Northern Territory. CSIRO C.1732; Timor Sea; Sept. 22, 1949, 1 (151). CSIRO C.725; Timor Sea; 1 (139). CSIRO C.1727; Joseph Bonaparte Gulf, Timor Sea; Sept. 12, 1949; 1 (135). CSIRO C.1731; Timor Sea; Sept. 22, 1949; 1 (131). CSIRO; Timor Sea; Sept. 22, 1949; 1 (48.2).

Western Australia. AMNH uncat.; Bush Bay, 20 mi. S. of Carnarvon; D. E. Rosen G. J. Nelson, and W. H. Butler; DER 69–51; 11 (68.5–105).

Hyporhamphus dussumieri (Valenciennes)

Fig. 20, Table 10

Hemiramphus Dussumieri Valenciennes *in* Cuvier and Valenciennes, 1846: 33–5 (original description; Seychelles Islands). Whitley, 1927: 10 (Michaelmas Cay [AMS IA.2733–5], N. Qld.). Marshall, 1964: 100 (listed, N. Qld.).

Hemiramphus Reynaldi Valenciennes *in* Cuvier and Valenciennes, 1846: 39–40 (original description; Trincomalee, Ceylon and Calcutta, India).

Hyporhamphus dussumieri.—McCulloch, 1929: 102 (listed; Qld. included in range). Munro, 1957: 55 (description, Qld.), fig. 394. Taylor, 1964: 106 (Arnhem Land [USNM 173778], N.T.; description). Whitley, 1964b: 38 (listed).

Misidentification:

Farhians marginatus.—Whitley, 1964a: 150 (Swain Reefs [AMS IB.6048], Great Barrier Reef).

Diagnosis

Similar to *Hy. affinis* but with a more prominent line of pigment along the ventral part of the lateral line (Fig. 20) and with a short preorbital distance, shorter than the length of the upper jaw. Lower jaw about as long as head. Preorbital canal with posterior branch (Fig. 2j–k); dorsal, ventral, and posterior branches of canal generally narrower than in *Hy. quoyi* but much wider than in *Hy. australis* or *Hy. melanochir*.

Description

Dorsal rays 15–17 in Australia (Table 10), usually 16, (14–18 elsewhere); anal rays 14–17 in Australia, usually 16, (14–18 elsewhere); pectoral rays 11 or 12; vertebrae (38–42) + (17–19) = 56–60 (52–56 elsewhere). Gill-rakers on first arch (9–12) + (25–28) = 33–40 in Australia, usually 35–37, (32–46 elsewhere); on second arch (3–7) + (21–25) = 25–33 in Australia, usually 26–28, (24–35 elsewhere). Pelvic fins located about midway between pectoral fin origin and caudal fin base; P_2–C extension falls on pectoral fin base or adpressed pectoral fin, usually on the anterior third of the adpressed fin in Australian specimens. Dorsal fin base much longer than anal fin base. Maximum body depth only slightly greater than maximum body width. Upper jaw width much greater than length.

Maximum known size

230 mm SL in Australia (USNM 206575, One Tree Is., Great Barrier Reef), 254 mm elsewhere.

Types

Hemiramphus dussumieri Valenciennes, 1846. Holotype MNHN B.1063; Seychelles Is.; Dussumier; 1830; 1 (254). Lower jaw length 44.5 mm; head length 53.0 mm; P_1–P_2 105 mm; P_2–C 98.2 mm; P_2–C extension falls just posterior to the pectoral fin base; D 15; A 15; P_1 11–11; RGR_1 14 + 32 = 46; RGR_2 5 + 29 = 34; posterior branch of preorbital canal present, ventral branch longer than dorsal or posterior branches (Fig. 2j).

Hemiramphus reynaldi Valenciennes, 1846. Syntypes MNHN B.1064; Trincomalee, Ceylon; Reynald; 1829; 2 (171–173); and MNHN A.7631; Calcutta; Dussumier; 1830; 1 (181). No lectotype is selected because of a lack of clear understanding of geographic variation in *Hy. dussumieri*. The dorsal and anal counts in the original description fit the syntype from Calcutta (16–15) but the description seems to have been based on Reynald's Ceylon specimens with Dussumier's Calcutta specimen being added in at the end of the description.

Geographic variation

There is significant geographic variation in meristic and morphometric characters within Australian waters and between Australian and extra-territorial populations of *Hy. dussumieri*. Final interpretation must await completion of a study of the species throughout its range. Variation within Australian waters and a partial outline of extra-territorial variation are treated here.

Table 10. Number of fin rays, gill-rakers, and vertebrae in some populations of *Hyporhamphus dussumieri* (* = holotype of *Hemiramphus dussumieri*)

Population	Dorsal Rays							Anal Rays						
	14	15	16	17	18	N	$\bar{x}$	14	15	16	17	18	N	$\bar{x}$
Indian Ocean	1	7*	11	2	1	22	15.77	2	5*	12	2	1	22	15.77
Oceania	9	25	3	..	..	37	14.84	13	23	1	..	..	37	14.68
New Guinea	7	49	2	..	..	58	14.91	31	26	1	..	..	58	14.48
Western Australia	..	3	3	..	..	6	15.50	2	4	..	..	..	6	14.67
Arnhem Land	..	1	1	..	..	2	15.50	..	1	1	..	..	2	15.50
Capricorns	..	11	18	2	..	31	15.71	..	3	25	3	..	31	16.00
Other Barrier Reef	..	9	32	1	..	42	15.81	..	9	32	1	..	42	15.81
Total, Barrier Reef	..	20	50	3	..	73	15.77	..	12	57	4	..	73	15.89

Population	First Arch Gill-rakers																
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	N	$\bar{x}$
Indian Ocean	1	1	5	1	3	4	..	1	2	..	2	1	1	..	1*	23	37.48
Oceania	..	..	..	..	3	1	6	8	6	3	2	2	..	..	..	31	39.29
New Guinea	..	..	..	..	1	8	7	18	7	7	2	2	1	..	..	53	39.26
Western Australia	..	..	..	..	..	..	..	..	4	..	..	1	..	..	..	5	40.60
Arnhem Land	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	2	37.50
Capricorns	..	1	5	5	7	10	2	..	..	..	..	..	..	..	..	30	35.87
Other Barrier Reef	..	..	2	10	13	6	1	1	..	..	..	..	..	..	..	33	35.91
Total, Barrier Reef	..	1	7	15	20	16	3	1	..	..	..	..	..	..	..	63	35.89

Population	Second Arch Gill-rakers													
	24	25	26	27	28	29	30	31	32	33	34	35	N	$\bar{x}$
Indian Ocean	3	1	3	6	3	1	..	1	1	..	2*	..	21	27.67
Oceania	..	..	..	..	2	4	14	1	8	2	..	1	32	30.63
New Guinea	..	..	..	..	3	5	13	12	13	3	4	1	54	31.05
Western Australia	..	..	..	..	...	..	..	2	2	1	..	..	5	31.80
Arnhem Land	..	..	..	..	..	1	..	..	..	..	..	..	1	29
Capricorns	..	7	6	7	6	2	1	1	..	..	..	..	30	26.90
Other Barrier Reef	..	..	4	11	8	4	2	1	..	..	..	..	30	27.73
Total, Barrier Reef	..	7	10	18	14	6	3	2	..	..	..	..	60	27.32

Population	Vertebrae										
	52	53	54	55	56	57	58	59	60	N	$\bar{x}$
Indian Ocean	..	..	..	3	10	..	..	..	..	13	55.77
Oceania	..	3	6	1	..	..	..	..	..	10	53.80
New Guinea	1	3	25	21	1	..	..	..	..	51	54.35
Western Australia	..	..	..	..	..	6	..	..	..	6	57.00
Arnhem Land	..	..	..	..	1	1	..	..	..	2	56.50
Capricorns	..	..	..	..	..	..	5	17	5	27	59.00
Other Barrier Reef	..	..	..	..	1	3	23	3	.	30	57.93
Total, Barrier Reef	..	..	..	..	1	3	28	20	5	57	58.44

As a group, the Australian specimens have more vertebrae (56–60 vs. 52–56), and more dorsal and anal fin rays (modally 16–16 instead of 15–14 or 15–15) (Table 10). In the number of gill-rakers on both the first and second arches, the Australian specimens generally have fewer gill-rakers than do specimens from New Guinea and Oceania, but about the same number as some specimens from the Indian Ocean (Table 10). However, the wide range in gill-raker counts for the Indian Ocean specimens (32–46, N = 23) compared to the New Guinea sample (36–44, N = 53) suggests that there may be two taxa among the Indian Ocean specimens.

This general picture is further complicated by differences between Australian specimens. The population in the Capricorn Group is the most different of the Australian populations from the population in New Guinea. Specimens from farther north on the Great Barrier Reef are slightly more similar to New Guinea specimens. The modal number of vertebrae in the Capricorns is 59 (range 58–60); the modal number on the rest of the Barrier Reef is 58 (range 56–59). Barrier Reef specimens are separable from New Guinea specimens on the basis of vertebral number. However, the two specimens from Arnhem Land (56 and 57 vertebrae) and the six from Western Australia (all with 57 vertebrae) are intermediate between the New Guinea and Barrier Reef populations. In number of gill-rakers and anal fin rays, the Arnhem Land specimens fit the Barrier Reef population reasonably well but the Western Australian specimens agree with the New Guinea population.

Morphometric differences were also found between some of the Australian populations. Analysis of covariance tests were run for the regressions on standard length of eight characters for the two largest samples, One Tree Island in the Capricorns versus Little Hope Island and Endeavour Reef south of Cooktown. Significant differences were found in the heights for three characters: head length, P_1–P_2 distance, and upper jaw width. To increase the sample size and avoid comparing only local subpopulations, the One Tree sample was combined with specimens from Heron Island to form a Capricorn sample and this was tested against the combined specimens from the rest of the Great Barrier Reef to the north. The heights of head length and upper jaw width were still significantly different. The P_1–P_2 distance was no longer different but the slopes of anal base length were.

Upon first comparing the Capricorn population with samples from the Indian Ocean, Oceania, and New Guinea, it seemed necessary to recognize a separate subspecies from the Barrier Reef. Material recently collected from Little Hope Island and Endeavour Reef and six specimens from Western Australia have led me to wait until I have completed a thorough study of geographic variation in *Hy. dussumieri* before describing any new taxa.

Distribution

A wide-spread tropical species found from Madagascar through the East Indies to the Philippines, New Guinea, Australia and Oceania. In Australia common on the Great Barrier Reef plus one collection from Arnhem Land and two collections from Western Australia.

Australian Material

218 specimens (27.6–230 mm SL) from 27 collections.

Queensland, 210 specimens (27.6–230 mm) from 24 collections arranged from north to south. CSIRO; Thursday I., Torres Strait; Oct. 26, 1949; 1 (47.7). IRSNB 16882; Lizard I.; Barrier Reef Exped.; Aug. 30, 1967; 1 (169). ANSP 117033; Little Hope I. N.W. of Endeavour Reef; J. C. Tyler; TS, A-8; Jan. 7, 1969; 3 (57.1–75.3). ANSP 117034; Endeavour Reef; J. C. Tyler and C. L. Smith; TS, A-13; Jan. 13, 1969; 1 (73.3). ANSP

117032; Little Hope I. N.W. of Endeavour Reef; J. C. Tyler and C. L. Smith; TS, A–20; Jan. 18, 1969; 52 (45.0–65.0); and USNM 206749; 40 (45.0–124); same data. ANSP 117031; coast W. of Little Hope I.; J. C. Tyler; TS, A–32; Jan. 25, 1969; 3 (93.4–110). AMS IA.2733–5, 2737; Michaelmas Cay off Cairns; T. Iredale and G. P. Whitley; May–June 1926; 4 (137–156). AMS IA.2946; Michaelmas Cay off Cairns; C. Hedley; 1 (140). CSIRO; Keeper Reef, 30 mi. N.N.E. Cape Cleveland; Nov. 24, 1951; 1 (54.3). CSIRO; Bramble Reef, off Townsville; Nov. 14, 1953; 1 (29.2). CSIRO; Bramble Reef, off Townsville; Nov. 15, 1953; 5 (40.7–57.0). AMS IB.6048; Gillett Cay, Swain Reefs; AMS exped.; Oct. 1962; 1 (160). QM I.9304; Heron I., Capricorn Group; 1 (122). USNM 206562; Heron I., Capricorn Group; J. H. Choat; May 17, 1966; 4 (114–150). AMS I.15386–006; 1 mi. W. of Heron I.; B. Goldman and J. Paxton; Feb. 10, 1969; 1 (50.0). AMS FT–265; One Tree Is., Capricorn Group; 1 (129). USNM BBC–1383, 1386, 1394, 1401, 1406 (USNM 206559), 1407, 1411 (USNM 206560), 1416 (USNM 206575); One Tree I., Capricorn Group; B. B. Collette et al., 1969 One-Tree Exped.; Nov.–Dec. 1969; 89 (27.6–230).

Northern Territory. USNM 173778; Yirrkalla N. of Cape Arnhem; R. R. Miller 48–21; July 29–Aug. 11, 1948; 2 (158–166).

Western Australia. AMNH 40008; S. of Mandu Mandu Cr., North West Cape; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–59; April 14, 1969; 1 (116). AMNH 40010; S. of Mandu Mandu Cr., North West Cape; D. E. Rosen, G. J. Nelson, and W. H. Butler; DER 69–57; April 3, 1969; 5 (68.6–122).

Rhynchorhamphus georgii (Valenciennes)

Fig. 21

Hemiramphus Georgii Valenciennes *in* Cuvier and Valenciennes, 1846: 37–9 (original description; Bombay and Coromandel, India). Marshall, 1951: 2 (Magnetic I., Qld. [FBQ 39], new Australian record). Marshall, 1964: 100 (Qld., listed).

Hemiramphus Russeli Valenciennes *in* Cuvier and Valenciennes, 1846: 32–3 (original description; Pondichery, India).

Hemiramphus leucopterus Valenciennes *in* Cuvier and Valenciennes, 1846: 48 (original description; Bombay, India).

Hemiramphus Eclancheri Valenciennes *in* Cuvier and Valenciennes, 1846: 51–2 (original description; "Marquesas Is.").

Hemirhamphus Cantori Bleeker, 1866: 145–6 (original description; E. Indies).

Loligorhamphus normani Whitley, 1931b: 105–6 (original description, genus and species; Townsville, Qld.), pl. 12, figs 2–3. Munro, 1957: 57 (description, N. Qld.), fig. 405 (after Whitley, 1931b). Whitley, 1964b: 39 (listed). Marshall, 1964: 98 (after Whitley, 1931b), pl. 24, fig. 6 (after Whitley, 1931b). Marshall, 1966: 174 (after Whitley, 1931b), pl. 24, fig. 6 (after Whitley, 1931b). Grant, 1972: 62 (brief description).

Rhynchorhamphus georgii.—Munro, 1957: 55 (Qld., description, fig. 391). Whitley, 1964b: 39 (listed). Grant, 1965: 36 (uncommon in Qld. waters). Grant, 1972: 60 (repeat of 1965 ed.).

Diagnosis

A peculiar species of garfish that differs from all Australian species in having a large domed upper jaw, a fimbriate nasal papilla (Fig. 3 bottom), and a large number of gill-rakers, 52–67 on the first arch (compared to 18–39 in other Australian garfishes) and 45–61 on the second arch (compared to 15–33).

Description

Only five Australian specimens were available so this description is based on 52 specimens from throughout the range. Preorbital canal a long narrow tube with no posterior branch; one or two central pores in addition to dorsal and ventral openings (Fig. 1, c–f). Upper jaw much longer than wide. Dorsal fin rays 14–17, usually 15; anal rays 14 or 15; pectoral rays 10–12. Vertebrae (37–40) + (18–19) = 56–59. Gill-rakers on first arch (12–16) + (39–50) = 52–67; on second arch (6–10) + (38–52) = 46–62. Dorsal fin base much longer than anal fin base. Pelvic fins placed far posteriorly; P_1–P_2 much greater than P_2–C; P_2–C extension falls on the posterior third of the adpressed pectoral fin or posterior to the tip of the fin.

Maximum known size

207 mm SL in Australia (CSIRO, Wessel Is., N.T.), 231 mm elsewhere (AMS B.7517, Madras, India).

Types

Hemiramphus georgii Valenciennes, 1846. Holotype MNHN B.1062; Bombay; Dussumier; 1830; female, 185 mm. D 17; A 15; P_1 11–11; RGR_1 16 + 47 = 63; RGR_2 10 + 49 = 59; preorbital canal shown in Fig. 1c. Paratype MNHN B.1061; Mahé Bay, Coromandel, India; Dussumier; 201 mm.

Hemiramphus eclancheri Valenciennes, 1846. Holotype MNHN 4592; "Marquises"; Eclancher; 107 mm. D 16; A 15; P_1 11–11; RGR_1 13 + 41 = 54; RGR_2 7 + 40 = 47.

Hemiramphus leucopterus Valenciennes, 1846. Holotype MNHN B.1065; Bombay; Dussumier; 89.5 mm. D 15; A 14; P_1 11–11; RGR_1 12 + 43 = 55; RGR_2 6 + 46 = 52.

Hemiramphus russeli Valenciennes, 1846. Holotype MNHN B.1067; Pondichery, India; Sonnerat; 202 mm. D 14; A ?; P_1 ?–11; RGR_1 ?; head and half the skin fastened onto a stick.

Hemiramphus cantori Bleeker, 1866. Original description based on 62 specimens. Syntypes probably include BMNH 1866.5.2.16; Bleeker; 1 (166). D 15; A 15; P_1 10–10; RGR_1 14 + 43 = 57; RGR_2 8 + 45 = 53; and Rijksmus. Nat. Hist. Leiden 6953 (50 specimens).

Loligorhamphus normani Whitley, 1931. Holotype AMS IA.2319; Townsville, Qld.; W.E.J. Paradice; 126 mm. D 14; A 15; P_1 12–12; RGR_1 14 + 44 = 58; RGR_2 9 + 45 = 54; preorbital canal shown in Fig. 1d.

Discussion

Rhynchorhamphus has been considered monotypic until recently when Parin and Shcherbachev (1972) and I independently discovered a second species which they described as *R. arabicus* based on two specimens from southern Yemen. I have four additional specimens (MCZ 41922) from Aden Harbour and can confirm the validity of *R. arabicus* which has even more gill-rakers (69–78 on the first arch compared to 52–67) than *R. georgii*. A revision of *Rhynchorhamphus* was nearly complete at the time the present paper was submitted.

Distribution

Known from the Indian Ocean, the East Indies, the South China Sea, the Philippine Islands, and northern Australia. In Australia, known only from eastern Queensland and the Northern Territory.

Australian Material

5 specimens (126–207 mm SL) from 5 collections.

Queensland. AMS IA.2319; off Townsville; W. E. J. Paradice; HMAS "Geranium", 1 (126); holotype of *Loligorhamphus normani* Whitley. BMNH 1927.2.10.21; off Townsville; W. E. J. Paradice; HMAS "Geranium"; Aug. 1924, 1 (132). FBQ 39; Horseshoe Bay, Magnetic Is.; G. Coates; Sept. 1949; 1 (179). FBQ 3608; off Cairns; 1 (164).

Northern Territory. CSIRO; Jensen Bay, Wessel Is.; July 28, 1949; 1 (207).

Zenarchopterus buffonis (Valenciennes)

Hemiramphus buffonis Valenciennes *in* Cuvier and Valenciennes, 1846: 48–9 (original description; Pulo-Pinan).

Zenarchopterus buffonis.—Marshall, 1951: 2 (Townsville, Qld., new Australian record). Munro, 1957: 57 (tropical Qld., description), fig. 407. Whitley, 1964b: 39 (listed). Taylor, 1964: 108–9 (description; Arnhem Land [3 USNM collections], N.T.). Munro, 1964: 146 (listed, Leichhardtian region—tropical Australia). Marshall, 1964: 102 (N. Qld.). Collette, 1966: 3 (listed). Grant, 1972: 66 (N. Qld. estuarine species).

Misidentification:

Zenarchopterus dispar.—Whitley, 1954: 28–9 (Depuch, W.A. [AMS IB.2640], new W.A. record).

Diagnosis

A species of *Zenarchopterus* which differs from all other species in the genus in having a prominent dark brown stripe along the midline of the snout. Upper jaw distinctly wider than long; width divided by length 1.05–1.35, $\bar{x}$ 1.16. Sixth anal ray of adult males expanded and somewhat elongated, but not reaching base of caudal fin. Fourth to seventh dorsal rays of adult males slightly elongated.

Description

Dorsal rays 11 or 12, rarely 13; anal rays 12 or 13; pectoral rays 10 or 11. Predorsal scales 27–32. Vertebrae (27–31) + (11–13) = 40–44. Pectoral fin much shorter than head; head length divided by pectoral length 1.48–6.07, $\bar{x}$ 4.73. Lower jaw much longer than head; head length divided by lower jaw length 0.50–0.66, $\bar{x}$ 0.56.

Maximum known size

117 mm SL (AMS IB.2640, Depuch Is., W.A.).

Types

MNHN B.1076; Pulo Pinan; Dussumier; 1830; 6 (53.3–74.0); 3 additional syntypes MNHN B.2184; 52.6–69.0 removed because they appear to represent another species.

Distribution

Andaman Islands, Malay Peninsula, East Indies, Philippine Islands and northern Australia. Across northern Australia from Gladstone Harbour, Queensland through Arnhem Land, Northern Territory, to Port Hedland and Depuch Island, Western Australia.

Australian Material

68 specimens (7.3–117 mm SL) from 10 collections arranged from east to west.

Queensland: USNM 206653; Gladstone Harbour; B. B. Collette 1417; Dec. 11, 1969; 14 (7.3–42.2). CSIRO; Mary R.; Aug. 25, 1950; 1 (86.5). AMS IB.1234–6; Fitzroy R.; G. P. Whitley; 3 (70.3–98.5).

Northern Territory: USNM 173768; west side Port Bradshaw, S. of Cape Arnhem; R. R. Miller 48–28; July 25, 1948; 21 (45.5–74.0); and AMS I.16153–001; 10. USNM 173766; Nightcliff, 7 mi. N. of Darwin; R. R. Miller and party; RRM 48–2; March 19, 1948; 5 (21.0–93.3). USNM 173767; Woods Inlet, 1 mi. W. of Delissaville Aboriginal Station near Darwin; R. R. Miller and P. Basset-Smith; RRM 48–5; March 26–30, 1948; 4 (73.4–111). SIO 61–701–23A; Darwin; Naga Exped. 61–257; April 21, 1961; 2 (89.1–91.4). AMS IA.7632; Northern Territory; M. Ward; 1 (101).

Western Australia: AMNH 40013; Port Hedland; D. E. Rosen, G. Nelson, and W. H. Butler; DER 69–75; April 13, 1969; 6 (38.4–69.4). AMS IB.2640; Depuch Is.; CSIRO; 1 (117).

Zenarchopterus caudovittatus (Weber)

Fig. 22

Hemiramphus (*Zenarchopterus*) *caudovittatus* Weber, 1908: 229–30 (original description; Merauke River, New Guinea), pl. 13, figs 1a, 1b.

Zenarchopterus caudovittatus.—Taylor, 1964: 106, 108 (Arnhem Land [USNM 173769], N.T.; description), pl. 15.

Misidentifications:

Hemirhamphus amblyurus.—Macleay, 1878: 364 (Port Darwin, N.T.). Macleay, 1881: 248 (Darwin; description). Taylor, 1964: 106 (references to Macleay papers).

Diagnosis

A species of *Zenarchopterus* which differs from the other four Australian species of the genus in its very long upper jaw, very long pectoral fin, and relatively short lower jaw. Upper jaw width divided by length 0.62–0.67, $\bar{x}$ 0.64 compared to 0.81–1.35 in the other four species. Pectoral fin about as long as head; head length divided by pectoral fin length 0.94–1.00, $\bar{x}$ 0.97 compared to 1.28–6.07 for the other four species. Head longer than lower jaw; head length divided by lower jaw length 1.31–1.79, $\bar{x}$ 1.56 compared to 0.50–0.75 for the other four species. *Z. caudovittatus* also has more vertebrae (46) than the other four species (38–42). Sixth anal ray of males widened but not elongated beyond rest of anal fin rays. None of the male dorsal rays elongated beyond the rest of the dorsal fin.

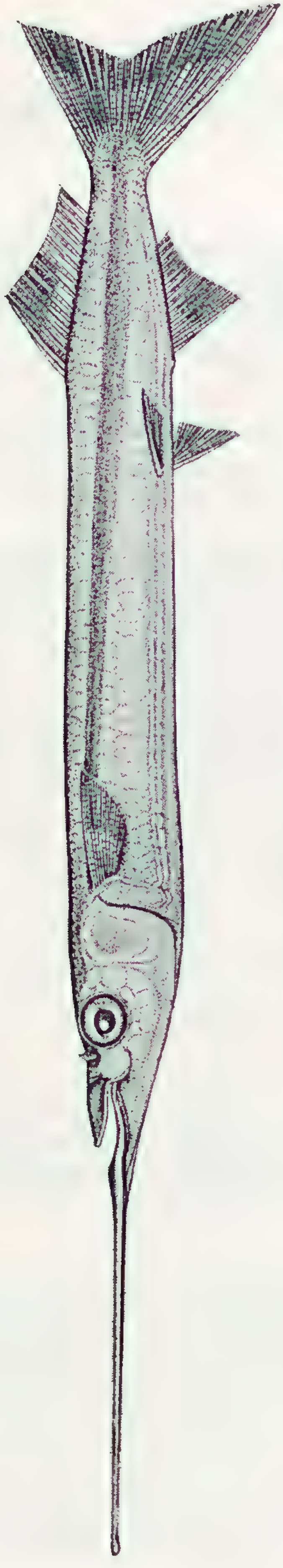


Figure 21. *Rhynchorhamphus georgii* USNM 138686, 161 mm SL, Borneo.

Description

Dorsal rays 12 or 13; anal rays 13 or 14; pectoral rays 10 or 11. Gill-rakers on first arch (4–5) + (11–14) = 16–18; on second arch 2 + (11–14) = 13–16. Vertebrae (30–32) + (14–16) = 46. Predorsal scales 30–32.

Maximum known size

111 mm SL in Australia.

Types

Not seen.

Discussion

The records of *Z. amblyurus* (Bleeker) by Macleay (1878 and 1881) from Darwin are herein referred to *Z. caudovittatus* because no Australian specimens of *Z. amblyurus*, = *Z. ectuntio* (Hamilton-Buchanan), have been located in any museum collections. *Z. caudovittatus* is similar to *Z. ectuntio* and different from all other Australian species of *Zenarchopterus* in its very long upper jaw.

Distribution

Merauke River, New Guinea and Arnhem Land, Australia.

Australian Material

USNM 173769; E. Alligator R., 6 mi. W. of Oenpelli, Arnhem Land; R. R. Miller and W. E. Harney; RRM 48–40; Oct. 13, 1948; 5 (43.7–111).

Zenarchopterus dispar (Valenciennes)

Hemiramphus dispar Valenciennes *in* Cuvier and Valenciennes, 1846: 58–62 (original description; ?Madagascar?).

Zenarchopterus vaisiganis Jordan and Seale, 1906: 208 (original description; Vaisigano River at Apia, Samoa), fig. 11.

Zenarchopterus dispar.—Ogilby, 1913: 92 (Torres Strait, Qld.). McCulloch and Whitley, 1925: 139 (Ogilby's 1913 record). McCulloch, 1929: 104 (Qld., listed). Munro, 1957: 57 (description; trop. Qld. and W.A.), fig. 406. Whitley, 1964b: 39 (listed). Marshall, 1964: 101 (Qld. mangrove swamps; description), pl. 25, fig. 110 and colour pl. 6, fig. 110. Marshall, 1966: 174 (Qld., listed), pl. 25, fig. 110 and colour pl. 6, fig. 110. Grant, 1972: 66 (brief description, Qld.).

Zenzarchopterus (sic) *dispar*.—Shipway, 1947: 27 (Cairns, Qld.; estuarine), fig. Carr, 1947: 4 (poisoned in Mitchell R., Qld.).

Diagnosis

A species of *Zenarchopterus* with the upper jaw distinctly wider than long; width divided by length 1.03–1.17, $\bar{x}$ 1.10. Snout uniform brown without any dark band on the midline. Pectoral fin shorter than head length; head length divided

by pectoral length 1.28–1.57, x̄ 1.38. Lower jaw much longer than head; head length divided by lower jaw length 0.52–0.65, x̄ 0.59. Anal rays 6 and 7 of adult males greatly thickened and elongated, both rays reaching well beyond the caudal base. Either dorsal ray 4 or 5 or both elongated and thickened.

Description

Dorsal rays 11 or 12; anal rays 12 or 13; pectoral rays 9 or 10. Gill-rakers on first arch (4–5) + (11–14) = 15–18; on second arch (1–2) + (11–14) = 13–15. Predorsal scales 29–36. Vertebrae 28 + (14–15) = 42–43.

Maximum known size

121 mm SL (QM I.7654, Magnetic Is., Qld.).

Types

Hemiramphus dispar. Syntypes MNHN 4594 and 4595; "Madagascar"; 5 (80.0–93.2).

Zenarchopterus vaisiganis. Syntypes USNM 51718 and AMS I.7385; Vaisigano River at Apia, Samoa; Jordan and Kellog; 4 males (89.7–98.7) plus 1 male (103).

Distribution

New Caledonia, Fiji, Samoa, Solomon Islands, New Guinea, and Australia. Australia distribution given as "tropical Qld. and W.A." by Munro (1957: 57) but I have seen specimens from only near Townsville, Queensland and from the Blackmore River near Darwin, Northern Territory.

Australian Material

7 specimens (72–121 mm SL) from 3 collections.

Queensland: AMS IB.3588; Townsville; E. Worrell; 5 (96.3–120). QM I.7654; Magnetic Is. off Townsville; 1 (121).

Northern Territory: AMS IB.4300; Blackmore River, S. part of Darwin Harbour; C. W. Holman; 1 (72).

Zenarchopterus gilli Smith

Hemirhamphus brevirostris Günther, 1866: 274 (original description; East Indies).

Zenarchopterus gilli Smith, 1945: 432 (new name to replace *He. brevirostris* Günther, preoccupied by *He. brevirostris* Cuvier). Taylor, 1964: 109–110 (Arnhem Land [4 USNM collections], N.T.; description). Collette, 1966: 3 (listed).

Misidentification

Z. dispar.—Stephenson *et al.*, 1931: 39 (Low Isles, [AMS IA.4467–8], Qld.). Whitley, 1932a: 277 (Low Isles, same specimens; description).

Diagnosis

A species of *Zenarchopterus* with the upper jaw about as long as wide; width divided by length 0.90–1.24, x̄ 1.03. Top of snout uniform brown, lacking the prominent dark line along the midline of the snout of *Z. buffonis.* Sixth anal ray of

males greatly enlarged and elongated, reaching the tip of the caudal fin in adults. Fourth dorsal ray of adult males elongated, thickened distally, curving back to the base of the caudal fin. Vertebrae fewer than in other Australian species of *Zenarchopterus*, 38–39 compared to 40–46.

Description

As Taylor (1964: 110) has pointed out, there is sexual dimorphism in dorsal and anal ray counts in *Z. gilli*. Females have 10 dorsal and 10–12 anal rays, usually 10 dorsal and 11 anal. Males have 11 or 12 dorsal and 13 anal rays, usually 11 dorsal and 13 anal. Pectoral rays 9 or 10. Predorsal scales 25–31. Gill-rakers 4 + (11–13) = 15–17 on the first arch; (1–2) + (12–13) = 14–15 on the second arch. Pectoral fin much shorter than head; head length divided by pectoral length 1.48–1.87, $\bar{x}$ 1.65. Lower jaw much longer than head; head length divided by lower jaw length 0.54–0.75, $\bar{x}$ 0.67. Vertebrae (25–27) + (11–14) = 38–39.

Maximum known size

72.2 mm SL in Australia.

Types

Not found.

Distribution

One of the most widespread species in the genus, reported from Madagascar, Mozambique, Seychelles I., Andaman Is., East Indies, Caroline Is., Fiji, and Guam as well as northern Australia. In Australia known from Mary R. and the Low Isles, Qld. and several localities in Arnhem Land.

Australian Material

129 specimens (24.1–72.2 mm SL) from 8 collections.

Queensland: CSIRO; Rocky Pt, Mary R.; Sept. 2, 1950; 3 (56.8–61.0). CSIRO; Deception Is. Narrows; Aug. 31, 1950; 1 (47.7). AMS IA.4467–8; Low Isles off Port Douglas; 3 (40.1–68.6).

Northern Territory: USNM 173763; Emerald R., Groote Eylandt; Gulf of Carpentaria; R. R. Miller and J. Blitner; RRM 48–15; 80 (24.1–65.4) and AMS IB.4712–3; 20. USNM 173764; Port Bradshaw, S. of Cape Arnhem, Gulf of Carpentaria; R. R. Miller 48–27; July 24, 1948; 15 (39.2–72.2). USNM 173765; Port Bradshaw; R. R. Miller 48–28; July 25, 1948; 6 (38.3–67.6). USNM 173880; East Point Reef, 6 mi. N.N.W. Darwin; R. R. Miller 48–3; March 26, 1948; 1 (26.0).

Zenarchopterus rasori (Popta)

Fig. 23

Hemiramphus rasori Popta, 1912: 192–3 (original description; Muna Is., Celebes).

Zenarchopterus rasori.—Taylor, 1964: 108 (Arnhem Land [USNM 173770], N.T.; description), pl. 16.

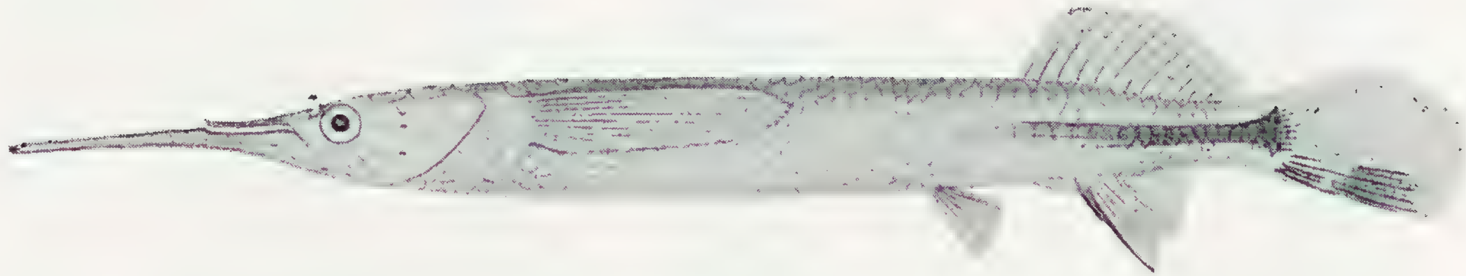


Figure 22. *Zenarchopterus caudovittatus*, USNM 173769, 99.4 mm SL, male, E. Alligator R., Arnhem Land, N.T. (From Taylor, 1964: pl. 15).

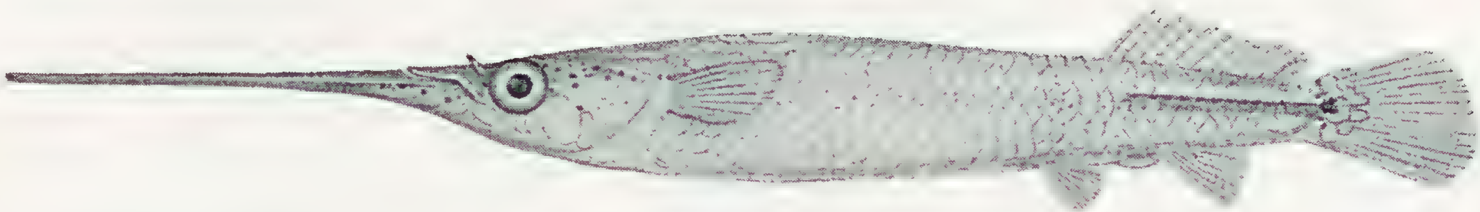


Figure 23. *Zenarchopterus rasori*, USNM 173770, 54.6 mm SL, female, Delissaville, Arnhem Land, N.T. (From Taylor, 1964: pl. 16.).

Diagnosis

A species of *Zenarchopterus* with the upper jaw slightly longer than wide; width divided by length 0.81–0.87, x̄ 0.84. This is shorter than in *Z. caudovittatus* (0.62–0.67) and longer than in the other three Australian species of the genus (0.90–1.35). Small black basicaudal spot present at end of lateral silvery band. Pectoral fin much shorter than head length; head length divided by pectoral length 1.76. Lower jaw much longer than head length; head length divided by lower jaw length 0.61–0.64, x̄ 0.63.

Description

Dorsal rays 11 or 12; anal rays 8 or 9; pectoral rays 9 or 10. Predorsal scales 26–29. Gill-rakers (3–4) + (8–12) = 12–15 on first arch; 1 + (9–12) = 10–13 on second arch. Vertebrae (27–29) + (12–13) = 41. Males unknown.

Holotype

SMF 6520; Raha, Muna Is., southeast Celebes; J. Elbert; 1909; Sunda Expedition; female (67.3 mm). D 11; A 9; P_1 9–9; RGR_1 4 + 8 = 12; RGR_2 1 + 9 = 10. Vertebrae 29 + 12 = 41.

Distribution

Muna Island, Celebes, and Arnhem Land, Australia.

Australian Material

USNM 173770; Woods Inlet, 1 mi. W. of Delissaville Aboriginal Station near Darwin, Arnhem Land; R. R. Miller and P. Basset-Smith; RRM 48–5; March 26–30, 1948; 2 females (54.6–59.8).

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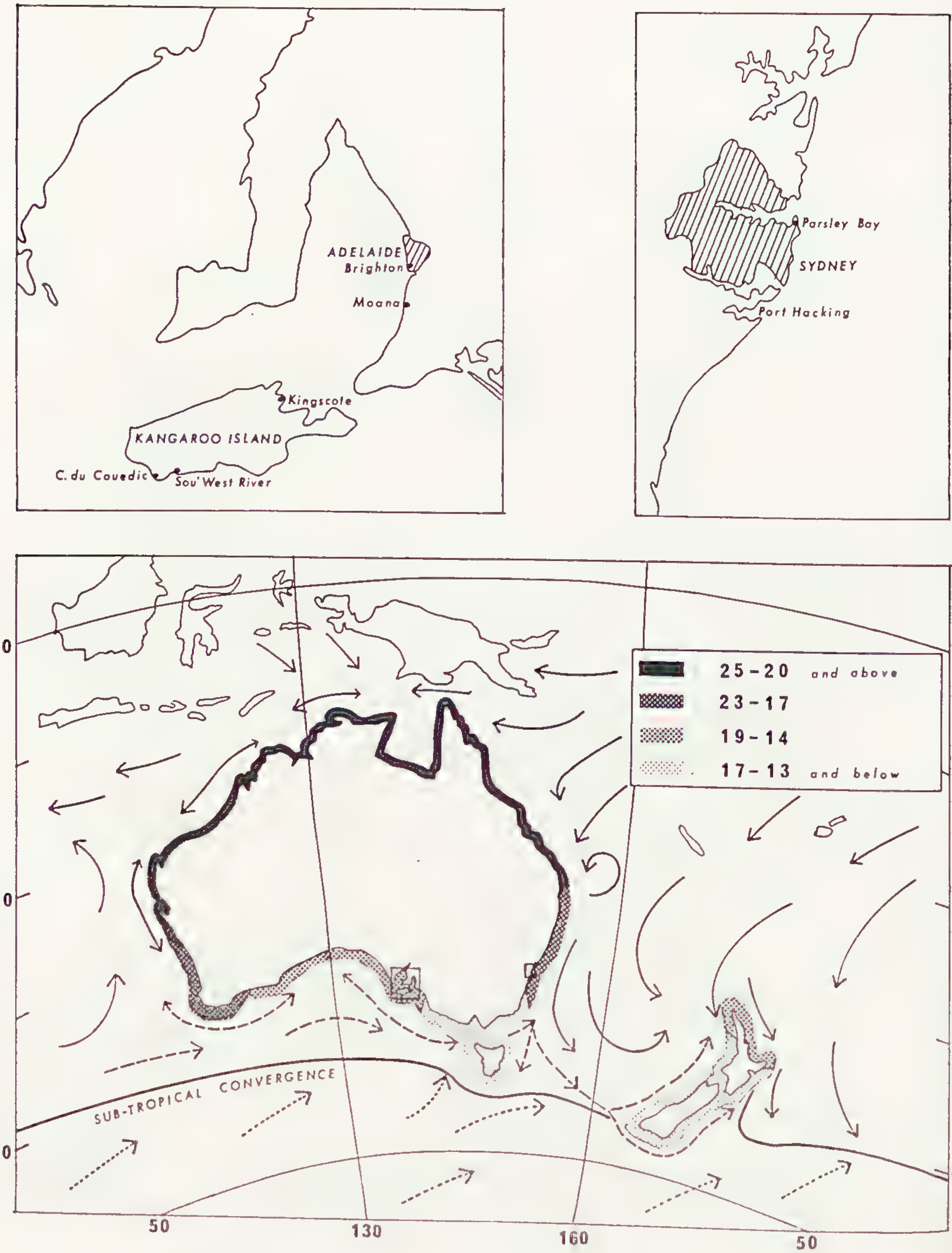

Figure 1.—Top left, collecting sites near Adelaide; top right, ditto near Sydney; bottom, collecting locations inset, showing also currents of warm, cool (interrupted lines) and cold water (dotted lines). A second smaller arrow-head indicates that the current occasionally reverses. Coastal water types and the mean position of the subtropical convergence (see p. 147) modified from Knox (1963), with mean summer (February) and winter (August) temperatures in degrees C.

SPIRORBINAE (POLYCHAETA: SERPULIDAE) FROM SOUTHEASTERN AUSTRALIA.

Notes on their Taxonomy, Ecology, and Distribution

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Figures 1–14 Manuscript received, 1st September, 1972

SUMMARY

Fifteen species belonging to seven genera are described, with pictorial and dichotomous keys to identification and notes on their distribution in other regions. All occur on or adjoining the shore, or on seaweeds cast ashore. Seven species are always attached to algae or *Amphibolis*. The predominant species are: near Sydney, *Eulaeospira convexis*, *Pileolaria pseudomilitaris*, *Janua formosa* and *J. pseudocorrugata;* near Adelaide (on cast weed), *Metalaeospira tenuis* and *Janua steueri;* and on Kangaroo Island, *Romanchella quadricostalis*, *Janua pagenstecheri* and (less commonly found) *Protolaeospira canina* and *Protolaeospira triflabellis*. *Janua lamellosa*, *J. fenestrata* and *J. trifurcata* seem scarcer, whilst only one specimen was found of the remarkable *Amplaria spiculosa*, which is now known from New Zealand.

Of these species, most of the opercular incubators are widespread in warm seas, but those which incubate in their tubes may be endemic and mostly belong to genera centred in the Southern Hemisphere, round which they may perhaps have been distributed by drifting kelp.

CONTENTS

INTRODUCTION

Collections were made by one of us (L. C. Llewellyn) at Brighton and Moanna, near Adelaide; at Kingscote, Sou-West River and Cape du Couedic on Kangaroo Island in January 1967; and at Parsley Bay, Vaucluse, Sydney in July 1967 (fig. 1). Seven of the species found were new and have now been described (Knight-Jones, 1973); two had been previously described from Port Hacking near Sydney by Wisely (1962), but the remaining six species are new records for Australia.

We now redescribe these eight previously known forms and offer a key for the identification of all fifteen species. The recent record by Straughan (1967) probably relates to one of these (p. 141). Earlier authors (Lamark, 1818; Mörch, 1863; Bush, 1904) who have dealt with Australian Spirorbinae have offered a few inadequate descriptions, several based on empty tubes and none including characters sufficiently distinctive for identification.

TECHNIQUES AND DIAGNOSTIC FEATURES

The best preservative is 5% formaldehyde made up with sea water, but plant substrata should not be included because they eventually produce acid conditions which decalcify tubes and opercula. Although 70% alcohol is excellent for observing the general morphology, the setae may thereafter be difficult to see, for specimens which have spent a few years in alcohol do not clear so readily after mounting (p. 112).

Identifications of Spirorbinae cannot be based on tubes alone, for these tend to vary with age, substratum and local conditions. There may be, for instance, only one longitudinal ridge on a young tube and three on an adult (p. 130). On rock the periphery of the tube may spread to form a flange, whereas the same species on algae may lack this. In crowded populations the last whorl may cover the previous whorls or form an ascending spiral instead of coiling flush with the substratum. Such tubes are often seen on filamentous algae where the area for attachment is limited. Some species have characteristically sculptured tubes (e.g., figs 2c and d), but such sculpturing may vary (p. 135). Direction of coiling seems to be constant for each species in the Australian material, but one of these, *Janua (Dexiospira) steueri*, occurs with both dextral and sinistral coiling in certain Red Sea locations (Sterzinger, 1909; Vine, 1972).

Figure 2.—Tubes (left) and opercula of eight sinistral species of Spirorbinae from southeast Australia: a, *Eulaeospira convexis;* b, *Metalaeospira tenuis;* c, *Romanchella quadricostalis;* d, *Protolaeospira triflabellis;* e, *Protolaeospira canina;* f, *Pileolaria militaris;* g, *Pileolaria pseudomilitaris;* h, *Amplaria spiculosa.* The tubes are all drawn to the scale shown, but the opercula are drawn to various larger scales. In a and b some opercular variations are illustrated, whilst f and g show juvenile forms in the centre and mature forms on the right.

Nevertheless, a few Australian Spirorbinae can be identified simply by inspecting the tube and the operculum, so pictorial keys showing these characters are given here for the eight sinistral species which we have found (fig. 2) and the seven dextral ones (fig. 3). All tubes are drawn to the same scale, but the opercula are more enlarged, to scales varying between species. Incubation within opercular brood-chambers is characteristic of three genera, *Pileolaria*, *Janua* and *Amplaria*, but not all adults contain embryos, whilst juveniles have opercula which are markedly different in form. The remaining Spirorbinae incubate within the tube and certain genera have characteristic ways of anchoring their embryos (Knight-Jones, Knight-Jones and Vine, 1972). A particularly characteristic feature is the special attachment stalk of *Protolaeospira* (fig. 4a), which may be seen in non-brooding adults.

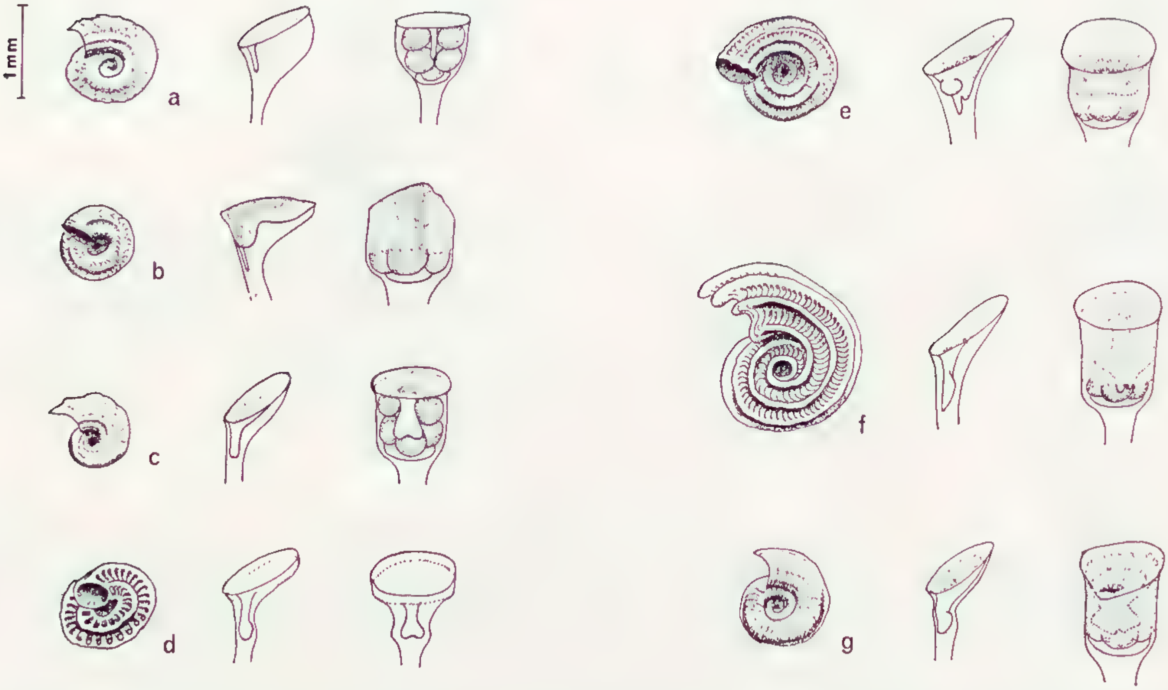


Figure 3.—As figure 2f, but illustrating dextral species. a, *Janua* (*Janua*) *pagenstecheri*; b, *Janua* (*Pillaiospira*) *trifurcata*; c, *Janua* (*Dexiospira*) *pseudocorrugata*; d, *Janua* (*Dexiospira*) *fenestrata*; e, *Janua* (*Dexiospira*) *lamellosa*; f, *Janua* (*Dexiospira*) *steueri*; g, *Janua* (*Dexiospira*) *formosa*. The tube g is only about 0.8 of the average mature size, but the others are typical for the species concerned. The juvenile opercula show the talons in side view, as they would appear in opercula protruding from their tubes. The others, which show the talons in face view, are newly mature. Old brood chambers of *Janua* species usually lack talons (e.g., figures 10d, 11h, 12g, 14f) and are not illustrated here because they are of little use in distinguishing species.

For certain identification the worm should be extracted by chipping away the tube with mounted needles under a dissecting microscope. The shape of the operculum (p in fig. 4a) can usually be studied in sea water or preservative by reflected light with a x5 binocular objective. In some species, however, the talon is large and characteristically sculptured (e.g., figs 2d and e), yet its finer details may be obscured by the ampulla wall, unless this is cleared in clove oil (after alcohol dehydration). Even then the opercula of several dextral species appear closely similar and these species can be distinguished only by examination of other characters.

One of the diagnostic features shared by five out of seven of the dextral forms is fusion of the margins of the thoracic collar on the dorsal side, i.e., the side which is next to the substratum (fig. 4k). This character is difficult to see in preserved material but the tunnel formed by the fusion can be demonstrated by inserting a mounted eyelash (Knight-Jones, 1972). One sinistral species in this collection also shows this feature (fig. 5). The remainder of the species have collar margins that are free dorsally (e.g., fig. 4a).

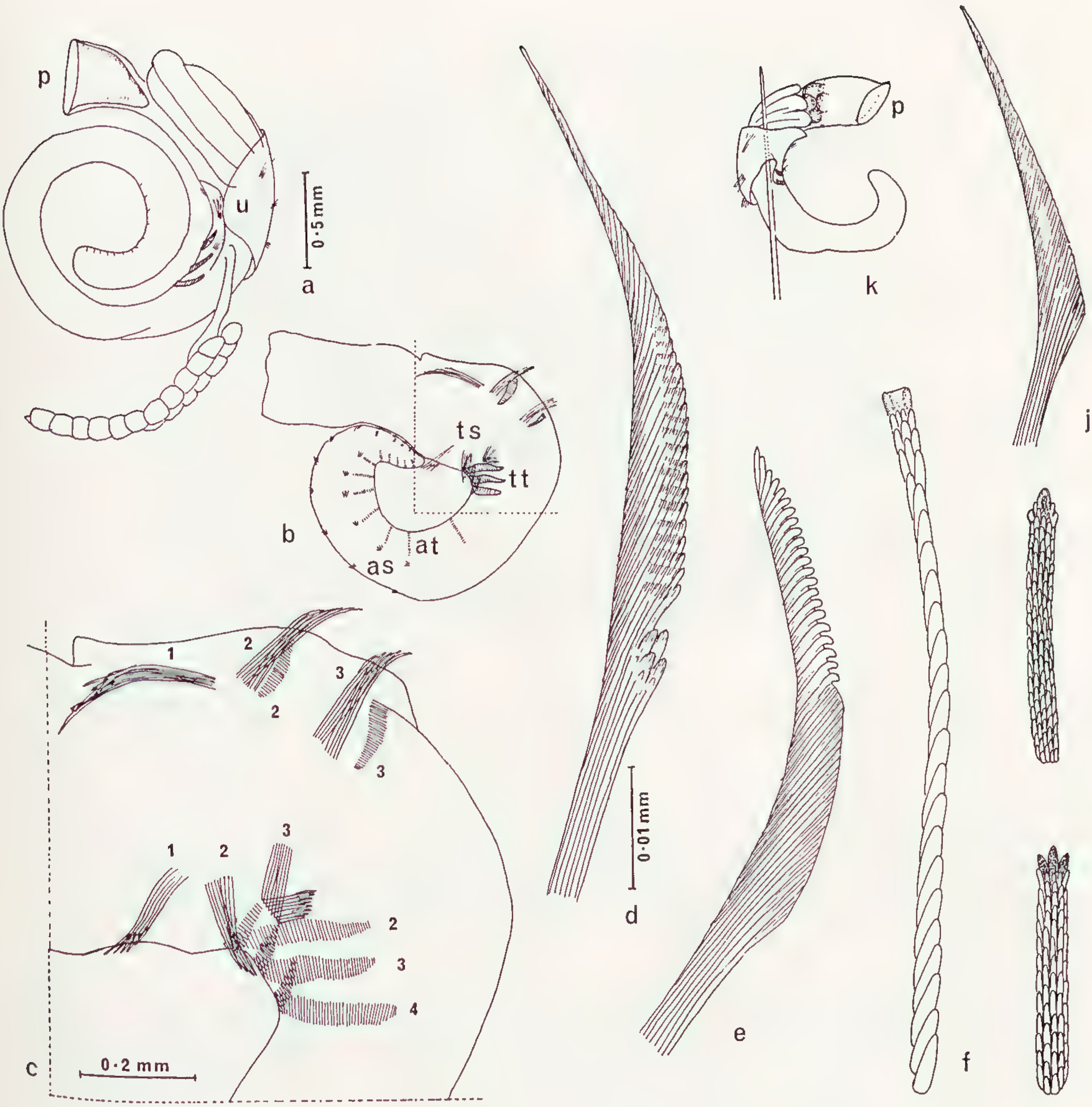


Figure 4.—a to f, *Protolaeospira canina;* g, *Janua* (*Dexiospira*) *trifurcata;* h to k, *Janua* (*Dexiospira*) *formosa.* a, dorsal view of whole animal as seen by reflected light, showing p, opercular plate with proximal talon and u, unfused dorsal margins of thoracic collar. b, dorsal view of animal with operculum removed, mounted in polyvinyl-lactophenol and viewed by transmitted light, showing as, abdominal setae; at, abdominal tori; ts, thoracic setae; tt, thoracic tori. c, as b, but more magnified, showing the setae and uncini of thoracic "segments" 1–4. d, seta from the first fascicles (a collar seta), showing proximal fin of large teeth and distal blade with a serrated outer margin and associated cross-striations. e, sickle seta from third fascicles. f, uncinus from a thoracic torus. g, thoracic uncinus with three-pronged anterior peg. h, ditto with pointed peg. j, simple seta. k, whole animal with collar folds fused dorsally, to form a tunnel demonstrated by an eye-lash probe; the opercular plate (p) surmounts a brood chamber which has the proxîma walls less calcified, showing the embryos within.

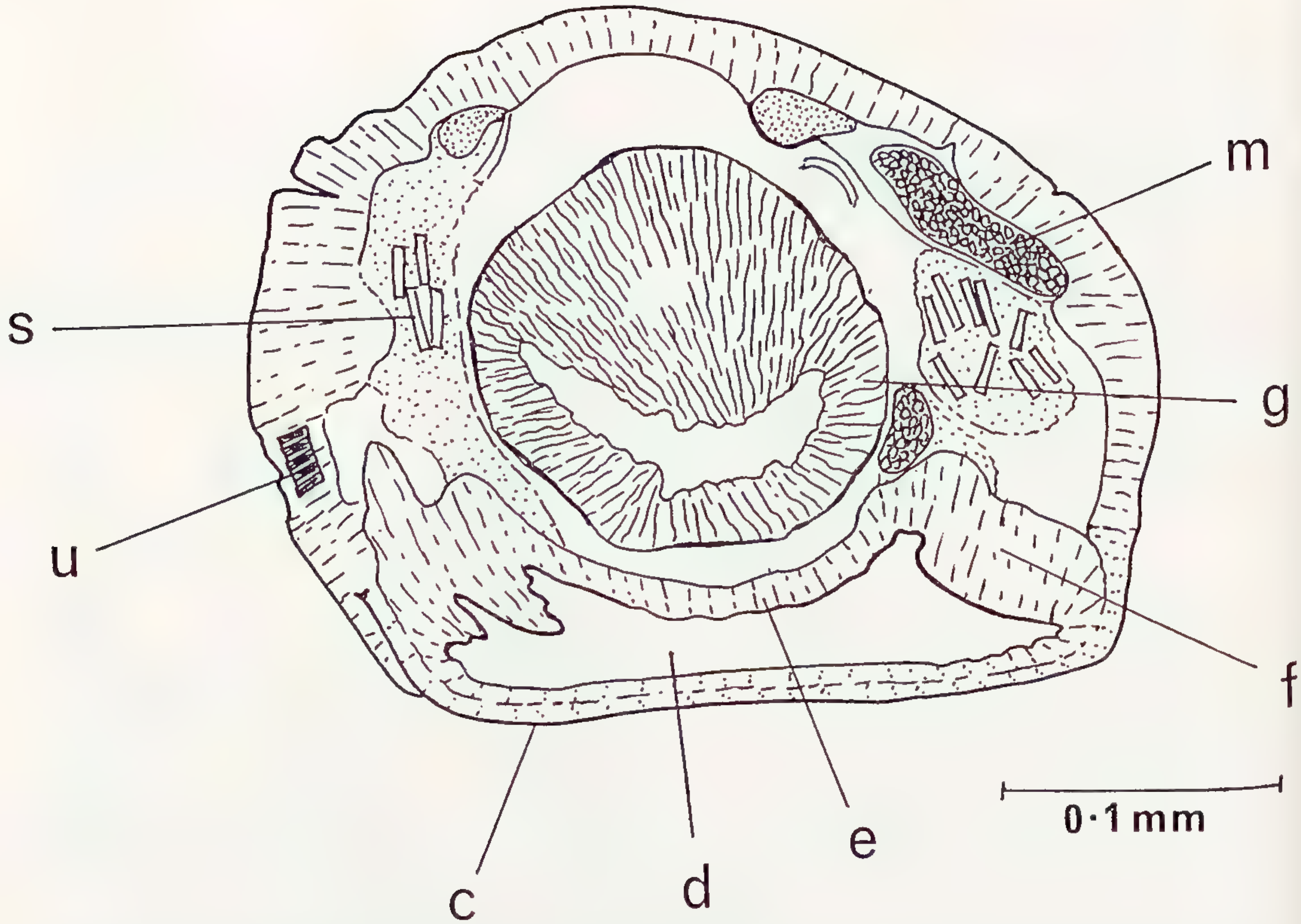
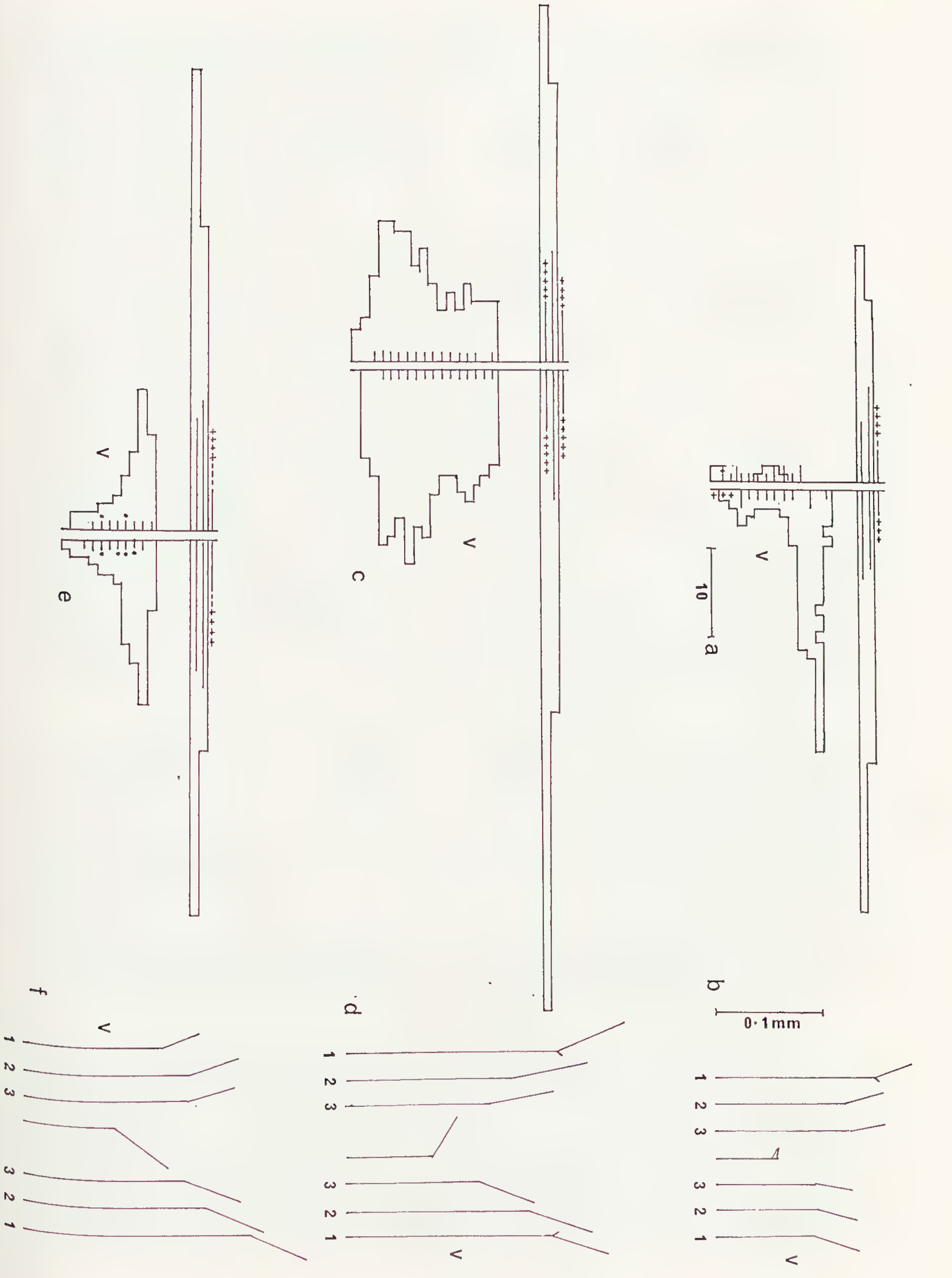


Figure 5.—*Romanchella quadricostalis.* Transverse section through midthoracic region, showing c, collar folds fused to enclose d, the dorsal (faecal) groove; e, epidermis of dorsal body-wall; f, thickened epidermis fringing dorsal groove; g, gut; m, longitudinal muscle on concave side; s, shafts of setae; u, uncini on convex side. The dorsal side is orientated downwards, because this is the side which adjoins the substratum.

OPPOSITE

Figure 6.—a and b, *Eulaeospira convexis;* c and d, *Pileolaria pseudomilitaris;* e and f, *Janua* (*Dexiospira*) *lamellosa.* On left, numbers of uncini per segment can be judged by applying the scale to histograms a, c and e. Each of these represents a worm straightened out, anterior end upwards, concave side marked "V", following the conventions of Bailey (1969b). The gap between thorax and abdomen represents the length of the asetigerous region relative to the length of the nearest abdominal segment. Numbers per segment of collar setae and simple setae (including abdominal setae) are represented to the same scale by straight lines. Indeterminate setae are shown by short dashes, whilst crosses denote capillary setae in thorax and hooked capillaries in abdomen; spots indicate the secondary setae found in the abdomen of *Janua.* On right, the relative length of shafts and blades are shown for different types of setae, all to same scale, following the conventions of Knight-Jones *et al.* (1973). In the centre of each diagram the largest abdominal seta is represented, whilst 1, 2 and 3 mark thoracic setae of the collar, 2nd and 3rd fascicles respectively, with V indicating those on the concave side of the body.

The number of thoracic tori on the concave side (e.g., two, three or four) is a useful generic character, often visible by reflected light at low magnifications. But high power examination of setae is necessary for conclusive specific identification, particularly of most dextral forms. For this the specimen should be mounted in the clearing agent polyvinyl-lactophenol (Knox, 1951) and viewed by transmitted light, preferably with high-power phase contrast. The preparation is improved if the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operculum is detached prior to mounting, to avoid the formation of CO_2 bubbles. Alternatively, covering may be delayed for a few hours, to allow bubbles to disappear. Warming the mount gently on a hot plate for about 48 hr improves the clearing of the tissues (Gee, 1964). Fig. 4b shows typical positions of the uncinigerous tori and fascicles of setae in such a mount. The collar setae differ from the other setae in that they point anteriorly. Since they are pivoted about the point of emergence through the skin, their deeply embedded setal sacs are displaced posteriorly, which may give the false impression that they originate in the second setigerous segment. Behind the collar setae all Spirorbinae may be said to have second and third thoracic segments, each represented by a pair of tori and a pair of fascicles. Some genera (e.g., *Metalaeospira* and *Protolaeospira*) have a fourth thoracic segment represented at least partially, by an extra torus on the concave side. Since there are no tori associated with the collar setae, the fascicles and tori of the concave side then seem to be out of phase (fig. 4c). In several species, including *Protolaeospira triflabellis* (p. 122), the fourth segment is represented on the convex side too, by an extra fascicle and/or torus. Exceptionally (in *Amplaria* and *Anomalorbis*—see pp. 129 and 143) the fourth segment is represented by all four setigerous rudiments and there are rudiments of a fifth thoracic segment, the most conspicuous of these being a fourth thoracic torus on the concave side. Fig. 4 also illustrates a few of the types of setae and uncini which are useful in identifying Spirorbinae. Collar setae are often of the fin and blade type (fig. 4d), but some genera (e.g., *Janua*) lack the proximal fins (fig. 4j). Either type of collar setae may be with or without cross-striations on the blades (e.g., fig. 4d), a useful character in separating some species. Sickle setae (fig. 4e) are characteristically found in the third fascicles, but are lacking in certain groups, such as the genus *Eulaeospira* (p. 118) and the subgenera *Simplicaria* (p. 126) and *Dexiospira* (p. 132). The thoracic uncini in two genera (*Protolaeospira* and *Pileolaria*) are characteristically elongated and thin, mostly bearing only a single row of teeth and with a blunt, indistinctly bifid peg (fig. 4f). In species of *Janua*, however, these uncini are shorter, but with several longitudinal rows of teeth and pointed anterior pegs (figs 4g and h).

Finally, the distribution of abdominal uncini and the relative lengths of abdominal setae, though not very useful in distinguishing species, can be important in characterising genera. All tube-incubating genera centred in the southern hemisphere (Knight-Jones, Knight-Jones & Vine, 1972) have a bilaterally asymmetrical distribution of abdominal uncini, those on the convex side being sparse or absent (fig. 6a), whilst the blades of their abdominal setae are relatively short (fig. 6b) and in *Protolaeospira* vestigial. The opercular incubating genera, on the other hand, have the uncini more symmetrically distributed. The sinistral genus *Pileolaria* is peculiar in having the largest abdominal tori towards the posterior end (fig. 6c), whereas the mainly dextral genus *Janua* (like most Spirorbinae) has the largest tori in the anterior half of the abdomen (fig. 6e). In *Janua* the blades of the abdominal setae are characteristically long, usually longer than those of the collar setae (fig. 6f).

The following key deals only with the species actually found in our material, yet it is likely that additional species are present in southeastern Australia, particularly below tide-marks, to judge from collections made in the region of the Great Barrier Reef (Vine, personal communication) and New Zealand (Vine, 1974). We have therefore thought it advisable to include, in the subsequent taxonomic section, diagnoses of the other genera and subgenera that may possibly be encountered off Australia. It should be noted that, although all species of *Janua* in the key are dextral, this group includes two sinistral subgenera (p. 142), at least one of which (*Leodora*) is likely to be encountered in this area.

The classification into genera used in this paper is mostly a compromise between the views of Bailey (1969b) and Pillai (1970), with amendments explained previously (Knight-Jones, 1972 and 1973). Diagnoses of the genera *Circeis* Saint-Joseph (1894), *Paradexiospira* Caullery and Mesnil (1897), *Prodexiospira* Pillai (1970), *Helicosiphon* Gravier (1907) and a few lesser-known taxa have not been included, because they seem to have restricted distributions, in the northern hemisphere or the Antarctic, and are unlikely to be represented in Australian waters.

KEY TO SPECIES FOUND IN SOUTH-EASTERN AUSTRALIA

1. Tube sinistral (mouth faces clockwise) 2
— Tube dextral 11

2 (1). Tube smooth, or with one obtuse longitudinal ridge 3
— Tube with distinct ridges 5

3 (2). Opercular plate or cap without proximal talon and not forming a brood chamber 4
— Opercular plate with proximal talon or forming a brood chamber 6

4. Tube round in cross section, lacking any ridges (figs 2a and 7a), opercular plate flat or slightly convex, some collar setae of the fin and blade type, no sickle setae, two thoracic tori on the concave side .... *Eulaeospira convexis* Wisely (p. 118)
— Tube almost triangular in cross section, with one obtuse longitudinal ridge (fig. 2b), opercular plate usually forming a truncated cone, collar setae simple, sickle setae in the 3rd fascicle, three thoracic tori on the concave side .... *Metalaeospira tenuis* Knight-Jones (p. 121)

5 (2). Tube with four very distinct longitudinal ridges (fig. 2c), collar setae simple, two thoracic tori on the concave side .... *Romanchella quadricostalis* Knight-Jones (p. 123)
— Tubes with transverse folds or less than four longitudinal ridges. Fin and blade collar setae 6

6 (3). Tube with transverse folds (fig. 2d) or with two longitudinal ridges, and a peripheral flange (fig. 2e). Opercular talon massive, three thoracic tori on the concave side, a thin stalk extends posteriorly from the thoracic region and embryos, if present, lie attached to this within the tube .... Genus *Protolaeospira* 7
— Tube rather round in cross section with indistinct longitudinal ridges or transverse growth striae (figs 2f and g), or rather square in cross section due to peripheral longitudinal ridges (fig. 2h). Operculum with talon (not massive) or forming a brood chamber 8

7 (6). Tube massive with conspicuous transverse folds, opercular talon blunt and with fluted sculpturing (fig. 2d) *Protolaeospira triflabellis* Knight-Jones (p. 122)
— Tube with two longitudinal ridges and a well developed peripheral flange, opercular talon pointed without distinct sculpturing (fig. 2e) .... *Protolaeospira canina* Knight-Jones (p. 122)

8 (6). Tube round in cross section, with indistinct longitudinal or transverse ridges; two thoracic tori on the concave side, juvenile opercular plate concave and with proximal talon, mature operculum forming a brood chamber .... Genus *Pileolaria* 9

— Tube rather square in cross section (having peripheral longitudinal ridges); four thoracic tori on the concave side, operculum forming a brood chamber 10

9 (8). Tube massive with indistinct longitudinal ridges, juvenile opercular talon with lateral wings and a centripetal spur, adult opercular brood chamber a deep 'helmet', which is rather bilaterally symmetrical and bears distal spines (fig. 2f), sickle setae present in third fascicles, a distinctive brown-black spot lies just behind the thorax . . *Pileolaria militaris* Claparède (p. 124)

— Tube with indistinct transverse growth striae, juvenile operculum with a short 'peg' talon, adult operculum a shallow spiny bilaterally asymmetrical helmet (fig. 2g), no sickle setae and no black spot .... *Pileolaria pseudomilitaris* Thiriot-Quiévreux (p. 126)

10 (8). Opercular plate with a flared continuous rim and a single distal spine (fig. 2h), thorax with the rudiments of five "segments" .... *Amplaria spiculosa* Knight-Jones (p. 129)

11 (1). Collar setae simple, juvenile opercular plate bears a somewhat peripheral talon, adult operculum forms a cylindrical brood chamber, a secondary plate develops below the embryo, forms the next distal plate and does not usually bear a talon. (It is difficult to identify some *Janua* species when the talon is absent) .... Genus *Janua* 12

12 (11). Sickle setae in third fascicles, collar margins separate dorsally, talon if present a simple peg (fig. 3a), not closely associated with the transparent wall of the brood chamber .... *Janua pagenstecheri* Quatrefages (p. 130)

— No sickle setae 13

13 (12). Collar margins separate dorsally, opercular plate bilaterally asymmetrical; young forms bear a peg talon, which is rather flattened and closely associated with the opaque wall of the brood chamber (fig. 3b); thoracic uncini with a three-pronged anterior peg (fig. 4g) .... *Janua* (*Pillaiospira*) *trifurcata* Knight-Jones (p. 142)

— Collar margins fused dorsally .... Subgenus *Dexiospira* 14

14 (13). Brood chamber with transparent walls, talon small and often bilobed terminally, but without distinct lateral wings or lobes 15

— Brood chamber with opaque walls, talon with distinct lateral wings or lobes 16

15 (14). Talon flat, somewhat triangular (fig. 3c) or subquadrangular in shape, tube bears 3 poorly defined ridges with indistinct transverse furrows between them .... *Janua* (*D.*) *pseudocorrugata* Bush (p. 132)

— Talon with two bulbous terminal lobes, tube bears three longitudinal ridges (one peripheral) which are separated and often tunnelled through by deep transverse furrows (fig. 3d) ...... *Janua* (*D.*) *fenestrata* Knight-Jones (p. 135)

16 (14). Talon large with bulbous lateral lobes formed by extensions of a transverse bar (fig. 3e). The bifid terminal part of the talon not in close association with the wall of the brood chamber (fig. 13e) .... *Janua* (*D.*) *lamellosa* Lamarck (p. 139)

— Talon, with flat angular lateral wings and terminal "lobes", all of which are closely associated with the walls of the brood chamber (figs 3f and g) 17

17 (16). Collar setae on the convex side with coarsely serrated and cross-striated blades, abdominal setae extremely long and narrow (fig. 14l), tube large with about four well defined ridges and intercostal furrows (fig. 3f) .... *Janua* (*D.*) *steueri* Sterzinger (p. 141)

— Collar setae with finely serrated blades lacking cross-striations, abdominal setae with fairly long but very wide blades (fig. 12m), tube small and often with rather indistinct ridges (fig. 3g) ...... *Janua* (*D.*) *formosa* Bush (p. 136)

SYSTEMATICS

Genus **Spirorbis** Daudin, amended

Coiling usually sinistral (see below); thorax with two pairs of tori; embryos incubated in an "egg string", which is attached posteriorly by a filamentous thread to the inside of the tube wall; collar folds separate dorsally; collar setae of fin and blade type, the blades with or without cross-striations; sickle setae present in the third fascicle; thoracic uncini with blunt anterior peg; abdominal setae obliquely geniculate, with fairly long tapering blades; distribution of abdominal uncini more or less bilaterally symmetrical, with the largest tori towards the anterior end of the setigerous region; larvae with a single white attachment gland.

Type: Serpula spirorbis Linnaeus, 1758.

Representatives of this genus are mainly confined to the northern hemisphere (Knight-Jones, Knight-Jones and Vine, 1972) and indeed to the north Atlantic. They have not yet been found in south-eastern Australia, but one, *Spirorbis* (*Spirorbis*) *bidentatus* Bailey (Bailey & Harris, 1968), which has been recorded at a depth of 50 metres off northern New Zealand (Vine, 1974), was originally described from shallow water in the Galapagos and may be expected to occur in Australian waters. Its tube (up to 1.5 mm across coil) bears 3 longitudinal ridges. Its opercular plate is slightly convex, with a massive talon which in side view shows a distinct almost terminal notch. Collar setae with a small gap separating a well defined fin from a blade that is not cross-striated.

Subgenus **Spirorbella** Chamberlain, 1919

As above for *Spirorbis*, but coiling dextral.

Type: Spirorbis marioni Caullery and Mesnil, 1897.

The range of variation of this species includes the forms *S. bushi* Rioja and *S. tricornigerus* Rioja (Vine, Bailey-Brock and Straughan, 1972). It is known from Panama, Hawaii and the Galapagos, so may possibly extend to northern Australia. It seems to be a close dextral relative of *Spirorbis* (*Spirorbis*) *cuneatus* Gee (1964), having a fairly massive talon, cross-striated collar setae and the teeth of the thoracic uncini arranged in transverse and longitudinal rows (most Spirorbinae have these teeth in diagonal and longitudinal rows).

Genus **Eulaeospira** Pillai, 1970, amended

Sinistral coiling; two pairs of thoracic tori; embryos incubated in the faecal groove; collar setae with blades lacking cross-striations, some with a basal fin; sickle setae absent; marked asymmetry in the distribution of abdominal uncini (fig. 6a); larvae probably lack white attachment glands.

Type: Spirorbis orientalis Pillai, 1960.

Eulaeospira convexis (Wisely, 1962)

Material

Holotype Australian Mus. W.3749; our material Australian Mus. W.4479.

Description

Tube small (under 1mm across coil), smooth, porcellaneous and thin-walled, round in cross section, sinistrally coiled in one plane or with the last whorl lying over the previous ones. The mouth of the tube may bear a thickened rim and occasionally a nearby additional thickening, probably denoting a period of renewed growth (fig. 7a).

Operculum with a thin, lightly-calcified distal plate, which varies in shape from convex (fig. 7d) to slightly concave (fig. 7e), but is usually of an intermediate shape with an asymmetrical depression (figs 7b and c).

Thorax. Collar margins not fused dorsally. Collar setae mostly of the fin and blade type (fig. 7g). The curvature of the region between the fin and blade (after which Wisely named the species) is not always apparent, as the distance between the fin and blade may be very small. The blades of other collar setae may have coarse teeth proximally, but with no gap separating them from the rest of the blade (fig. 7f), giving the appearance of simple setae. These occur more frequently on the concave side, but both types of setae have been found on each side. The setae of the second and third fascicles are simple, with blades almost smooth throughout their length (fig. 7h). Two pairs of tori. Each uncinus with a blunt, fluted anterior peg and four or more longitudinal rows of teeth, the rows more numerous in the smallest uncini at the end of a torus (figs 7k and l).

Abdomen. Asetigerous region about three times as long as the distance between the 1st and 2nd abdominal tori. About fourteen setigers with most of the uncini on the concave side (fig. 6a). Each uncinus has a blunt fluted anterior peg (fig. 7m). Setae strongly geniculate, with a short tapered blade bearing ovate teeth (fig. 7j). Hooked capillary setae may be present in some fascicles (figs 6a and 7j).

Incubation

In close association with the faecal groove but, owing to the small size of this species (and in spite of its abundance) the method of attachment was difficult to establish. Usually it seemed that the embryo mass (up to about 20 eggs) did not lie freely in the groove but adhered to the area between the third thoracic and second abdominal setiger. The egg mass could usually be dislodged intact, but there was often more resistance to detachment near the posterior position. In one specimen there seemed to be a tenuous attachment filament at about the second abdominal segment (fig. 7n). It would be interesting to see whether these attachments are present in fresh material.

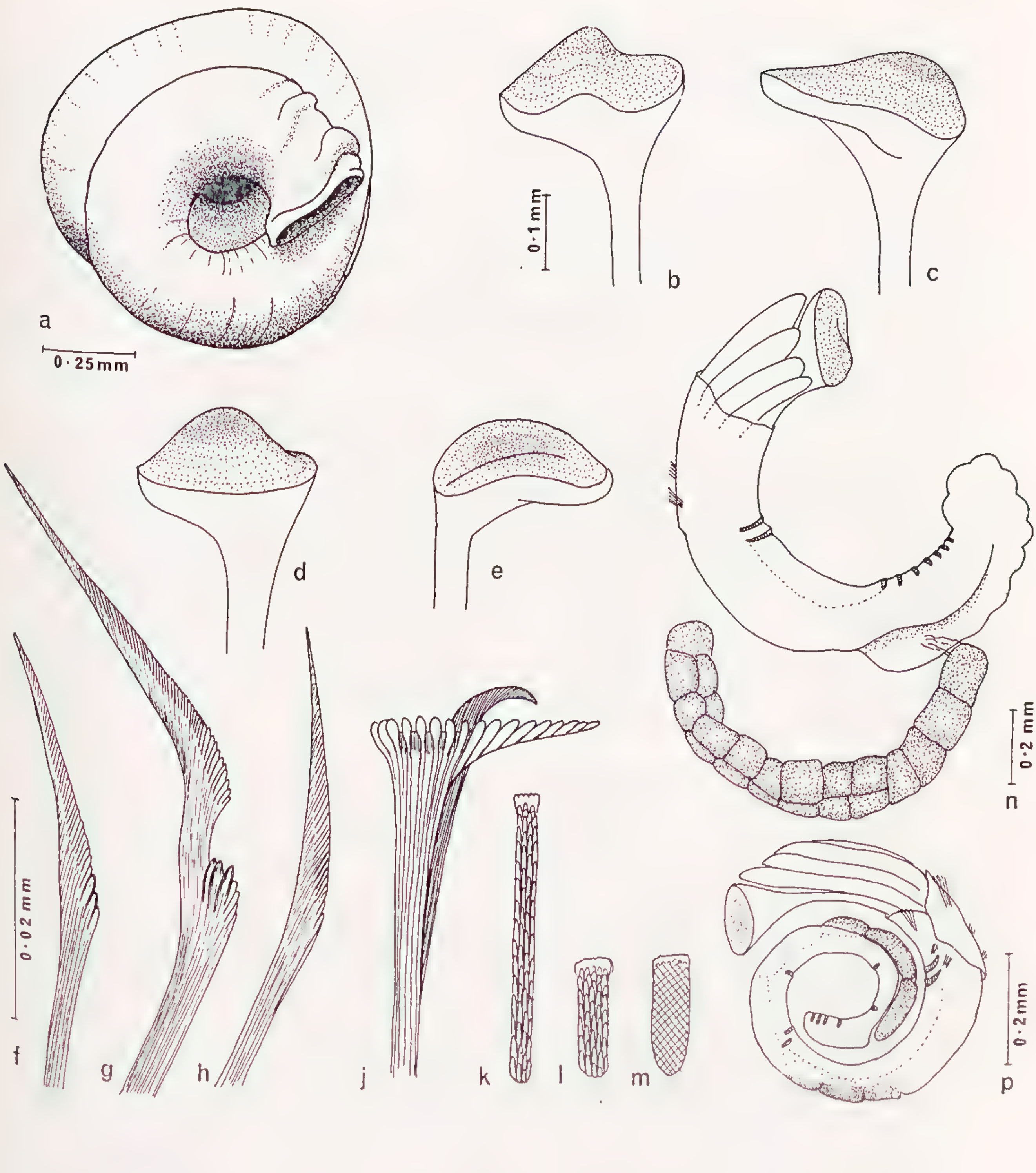

Figure 7.—*Eulaeospira convexis:* a, tube; b and c, typical operculum; d and e, extremes of opercular form; f, "simple" collar seta; g, fin and blade collar seta; h, seta of the second and third fascicles; j, abdominal seta and associated hooked capillary seta; k and l, largest and smallest thoracic uncini; m, abdominal uncinus (cross-hatching denotes longitudinal rows of teeth too small to depict); n, whole animal viewed from the ventral side, showing embryo mass which has been removed from the faecal groove, with what may be a posterior attachment filament. p, *Eulaeospira orientalis* paratype, whole animal (prior to mounting, slide deposited in B.M. Nat. Hist. showing typical flat opercular plate, long opercular stalk and embryos adhering along the faecal groove). Scales: c, d and e as b; g to m as f.

Locations

Previously found at Port Hacking, Sydney (Wisely, 1962). Abundant and widely distributed on marine plants in the Sydney and Adelaide areas (table 1, p. 144). Not recorded outside Australia.

Remarks

Pillai (1970) raised a new genus *Eulaeospira* for species which had the characteristics of *Spirorbis sensu stricto* but lacked sickle setae in the third thoracic fascicles. Paratypes of *Eulaeospira orientalis* Pillai and *E. convexis* (Wisely) were kindly loaned by the British Museum (Nat. Hist.) and compared with the above material. *E. orientalis* also shows marked bilateral asymmetry in the distribution of abdominal uncini (cf. Knight-Jones, Knight-Jones and Bregazzi, 1973), and embryonic masses "adhering" to the faecal groove (fig. 7p). The method of anchoring the embryos differs markedly from that known in *Spirorbis sensu stricto* and indeed from the methods known in all other genera of the Spirorbinae, except perhaps *Metalaeospira* (see p. 121).

Both *E. convexis* and *E. orientalis* show great variations in the size of the gaps between the fin and blade of the collar setae (there is often no gap at all). Another peculiarity is that both have many hooked abdominal capillary setae. Indeed, these were the *only* type present in the abdomen of one specimen of *E. orientalis* studied by Vine (1972). *E. orientalis* differs from *E. convexis* mainly in having a tube with a median ridge, a flat opercular plate, a remarkably long opercular stalk (fig. 7p), and uncini (both thoracic *and* abdominal) with four distinct anterior teeth, all similar in size.

Pillai also includes *E. variabilis* (Bush, 1904) in this genus. We have not examined this species, but it is interesting to note that Bush described it as incubating strings of eggs "along the back of the posterior segments".

Genus **Paralaeospira** Caullery & Mesnil, 1897, amended

Sinistral coiling; three thoracic tori on the concave side; embryos incubated in the region of the faecal groove but attached neither to the body nor to the tube; collar setae with fin and blades usually without cross-striations; thoracic uncini slender and with a blunt anterior peg; thoracic and abdominal uncini much more numerous on the concave side; largest abdominal tori occur towards the anterior end of the setigerous region; abdominal setae about half the length of the collar setae, with fairly short tapering blades.

Type: Spirorbis (Paralaeospira) aggregatus Caullery & Mesnil, 1897.

This is predominantly a southern genus with only one species known from the northern hemisphere (Knight-Jones, Knight-Jones and Vine, 1972) but it has not yet been found in Australia. It seems quite likely, however, that *Paralaeospira levinseni* Caullery and Mesnil (1897) may occur in the cooler waters of S. Australia and Tasmania, for this species is widespread in the southern ocean (Knight-Jones and Walker, 1973), occurring in South Africa, Chile (personal observations), New Zealand (Vine, 1974) and various Antarctic locations. It is found mainly on stones, shells and serpulid tubes, but sometimes on algae. The tubes are smooth (up to 2.5 mm) and may form aggregations. Many of them are then coiled irregularly. The operculum of the young form is a flat, lightly calcified disc, with a shallow ampulla, set rather asymmetrically on the opercular stalk. A small eccentric talon, variable in shape, develops later beneath the plate, which becomes asymmetrically convex. The collar setae are without cross-striations.

Genus **Metalaeospira** Pillai, 1970, amended

Sinistral coiling; three rows of thoracic tori on the concave side; embryos incubated in and attached to the faecal groove by tenuous threads (Knight-Jones, Knight-Jones and Vine, 1972); collar setae simple (without fins); thoracic uncini slender and with a blunt anterior peg; thoracic and abdominal uncini much more numerous on the concave side; tori large throughout most of the setigerous region; abdominal setae less than a quarter of the length of the collar setae and with vestigial brush-like blades.

Type: Spirorbis pixelli Harris, 1969 *nom. nov. pro Spirorbis antarcticus* Pixell (1913).

Metalaeospira tenuis Knight-Jones, 1973

Material

British Mus. (Nat. Hist.) holotype 1971:8; paratypes 1971:9; Australian Mus. paratypes W.4473.

Remarks

The specific name of this Australian species refers to the attenuated body and opercular "cap". The operculum is fragile and usually has a prominent distal cone in mature specimens, but the cone is truncated or even rather flat in younger specimens. The tube is thin-walled, porcellaneous and triangular in cross section, due to a single obtuse ridge. It has a large number of whorls which usually lie flat against the substratum (algae or marine angiosperms). The whorls increase regularly in size and height so that the central region forms a shallow dish-like depression (fig. 2b). A full description can be found in a recent paper (Knight-Jones, 1973).

Locations

Particularly abundant on *Jeannerettia* cast ashore on Brighton Beach, Adelaide. Also at Moanna and Kangaroo Island (table 1, p. 144).

Genus **Protolaeospira** (Pixell, 1912), redefined

Coiling usually sinistral (see below); three rows of tori on the concave side of the thorax; other traces of a fourth thoracic segment may or may not be present; embryos attached to a stalk which arises dorsally from the floor of the faecal groove in the thoracic region and towards the left side (fig. 4a); collar setae with separate fins and blades which are usually cross-striated (not in *Dextralia*—see below); sickle setae present in the third fascicle; thoracic and abdominal uncini much more numerous on concave side; thoracic uncini usually very long and slender, with a blunt, bilobed anterior peg; abdominal setae less than a quarter the length of the collar setae and with vestigial brush-like blades; opercular talon massive and usually bearing lateral projections; single white larval attachment glands may be present.

Type: Protolaeospira ambilateralis Pixell (1912).

This genus, of which *Marsipospira* Bailey (1969b) is a synonym, includes *Pixellia* Pillai (1970) and seems to be centred in the Southern Hemisphere, though a few species are found in the tropics and the north. Detailed comparison (Knight-Jones, Knight-Jones and Bregazzi, 1973) shows that it is very closely related to the Antarctic genus *Helicosiphon* Gravier.

Protolaeospira triflabellis Knight-Jones, 1973

Material

British Mus. (Nat. Hist.) holotype 1971:10, paratypes 1971:11; Australian Mus. paratypes W.4474.

Remarks

The opaque tube is easily distinguished from tubes of all other Australian Spirorbinae, by its large size and prominent transverse ridges (fig. 2d). The opercular talon is massive and opaque. It bears three irregular fluted projections which appear fan-like in dorsal view. The terminal "fan" is thick in profile and fluted on both sides.

Locations

On stones and *Ecklonia* holdfasts to the south-west of Kangaroo Island (table 1, p. 144).

Protolaeospira canina Knight-Jones, 1973

Material

British Mus. (Nat. Hist.) holotype 1971:12, paratype 1971:13; Australian Mus. paratypes W. 4475.

Remarks

The tube has two longitudinal ridges (the inner one the most prominent), with slight transverse grooves between them. A wide striated flange slopes down from the outer ridge and projects a little in front of the mouth, which may or may not ascend (fig. 2e). The opercular talon is large and in side view somewhat like a canine tooth, but a face view shows faint bulges on each side (one higher than the other) and an indistinct median longitudinal ridge.

Locations

On stones, to the south-west of Kangaroo Island (table 1, p. 144).

Subgenus **Dextralia** Knight-Jones, 1973

As above, for *Protolaeospira*, but with dextral coiling and lacking cross-striations on the blades of the collar setae.

Type: Spirorbis falklandicus Pixell (1913).

Only two species known, both from the south Atlantic (Knight-Jones and Walker, 1973).

Genus **Romanchella** Caullery & Mesnil, 1897

Sinistral coiling; incubation in an egg mass attached anteriorly by a stalk which arises dorsally, level with the thoracic tori and in the left side of the faecal groove; dorsal margins of the collar fused to form a tunnel over the faecal groove (fig. 5); simple collar setae; only two pairs of thoracic tori; sickle setae present in the third fascicles; abdominal setae strongly geniculate, with small tapered blades,

less than a quarter the size of the collar setae, and usually paired (though one of a pair is often a hooked capillary setae); thoracic uncini with a blunt anterior peg which is gouge-shaped and may therefore appear bilobed; abdominal uncini numerous on the concave side of the abdomen and sparse on the convex, with the largest tori near the anterior end of the setigerous region; white larval attachment glands probably not present.

Type: Spirorbis perrieri Caullery & Mesnil, 1897.

This species is widespread in the Southern Ocean. Other species are known from Tristan da Cunha (Harris, 1969) and New Zealand (Vine, 1974). This narrow definition of *Romanchella* excludes little known northern forms, such as "*Spirorbis*" *evolutus* Bush, which have collar margins separate dorsally and a rather symmetrical distribution of uncini. These are perhaps best placed in the genus *Sinistrella* Chamberlain (1919) and the taxon *Bushiella* Knight-Jones (1973) should lapse.

Romanchella quadricostalis Knight-Jones, 1973

Material

British Mus. (Nat. Hist.) holotype 1971:14, paratypes 1971:15; Australian Mus. W.4476.

Description

The tube is often irregularly coiled, with four or five high smooth longitudinal ridges, three of which form prominent teeth at the mouth. There are no intercostal markings. The concave opercular plate bears a shallow broad peripheral talon which is cleft terminally (fig. 2c). Sometimes the outer surface of the plate shows incipient delamination and occasionally two lobed plates may be seen, one above the other.

Locations

Common on marine plants south-west of Kangaroo Island (table 1, p. 144).

Genus **Pileolaria** Claparède, 1868; amended

Sinistral coiling; two pairs of thoracic tori; incubation in the operculum; collar margins not fused dorsally; each collar seta with a fin, separate from a blade which is usually coarsely serrated and cross-striated; sickle setae may or may not be present; thoracic uncini very slender with one to three longitudinal rows of teeth and a blunt anterior peg; abdominal setae obliquely geniculate (with tapering blades) and usually about half the size of the collar setae (fig. 6d); abdominal uncini fairly symmetrical in bilateral distribution (fig. 6c); larvae have single white, mid-dorsal attachment glands.

Subgenus **Pileolaria**

Opercular dimorphism between juveniles and adults; juvenile operculum usually more or less flat or even concave and with a proximal talon; adult operculum usually helmet-shaped, bilaterally symmetrical and forming a brood chamber; brood chamber lacks a talon, unless that term is applied to the calcified wall which forms the back of the helmet; there is no separate secondary plate or cup beneath the embryos; collar setae cross-striated; sickle setae always present in the third fascicle; the largest thoracic uncini usually with a single row of teeth for most of their lengths.

Type: Pileolaria militaris Claparède (1868).

Pileolaria (Pileolaria) militaris Claparède

Material

Australian Mus. W.4480.

Description

Tube sinistral, large, often loosely coiled (sometimes ascending) with irregular growth rings and sometimes three faint longitudinal ridges (fig. 8a).

Opercular plate of the juvenile form is concave and has an eccentric talon, with lateral wings and a central spur (figs 8b and c). The helmet-shaped form of operculum may have an encircling symmetrical distal rim (fig. 8e), but usually the rim is absent or vestigial on the side away from the branchial crown (figs 8d and f) and may bear distal papillae (figs 8e and f). In well-developed opercula there are numerous spines within the rim and often one or two outside it (fig. 8d).

Thorax. Collar setae with fin and coarsely serrated, cross-striated blade (fig. 8g) accompanied by capillary setae. The second and third fascicles have simple setae (fig. 8h), with additional sickle setae (fig. 8j) in the third fascicles. Each thoracic uncinus has a blunt anterior peg followed by a few small teeth, but a single row of large teeth for most of its length (fig. 8k).

Abdomen with characteristic black patch in the position of the asetigerous region. The latter is relatively short, measuring about three times the length of the distance between the 1st and 2nd abdominal tori. It is followed by about nineteen setigers, bearing uncini which have approximately five longitudinal rows of teeth and a blunt anterior peg (fig. 8l). The setae are obliquely geniculate with sharply tapering blades (fig. 8m).

Incubation

In the operculum.

Locations

On stones and shells from Kangaroo Island and Sydney (see table 1, p. 144).

Remarks

This material was compared with *S. superbus* Pillai (1960), kindly made available by the British Museum of Natural History, and with specimens of *P. militaris* from Malta and Plymouth, U.K. The main difference between the Australian material and that from other locations is the presence of faint longitudinal ridges on the earlier whorls of the Australian tubes.

This difference seems insignificant, for tube variability is often associated with local conditions (Gee, 1964–see also pp. 108 and 135). The range of opercular variation of the material examined tends to confirm the suggestion of Zibrowius (1967 and 1968) that *Spirorbis beneti* Marion (1879), *S. cornuarietis* Phillipi in Marion & Bobretzky (1875), *S. serratus* Bush (1910), *S. mendosus* Bush (1910), *S. papillatus* Pixell (1913) and *S. superbus* Pillai (1960) are synonymous with this species.

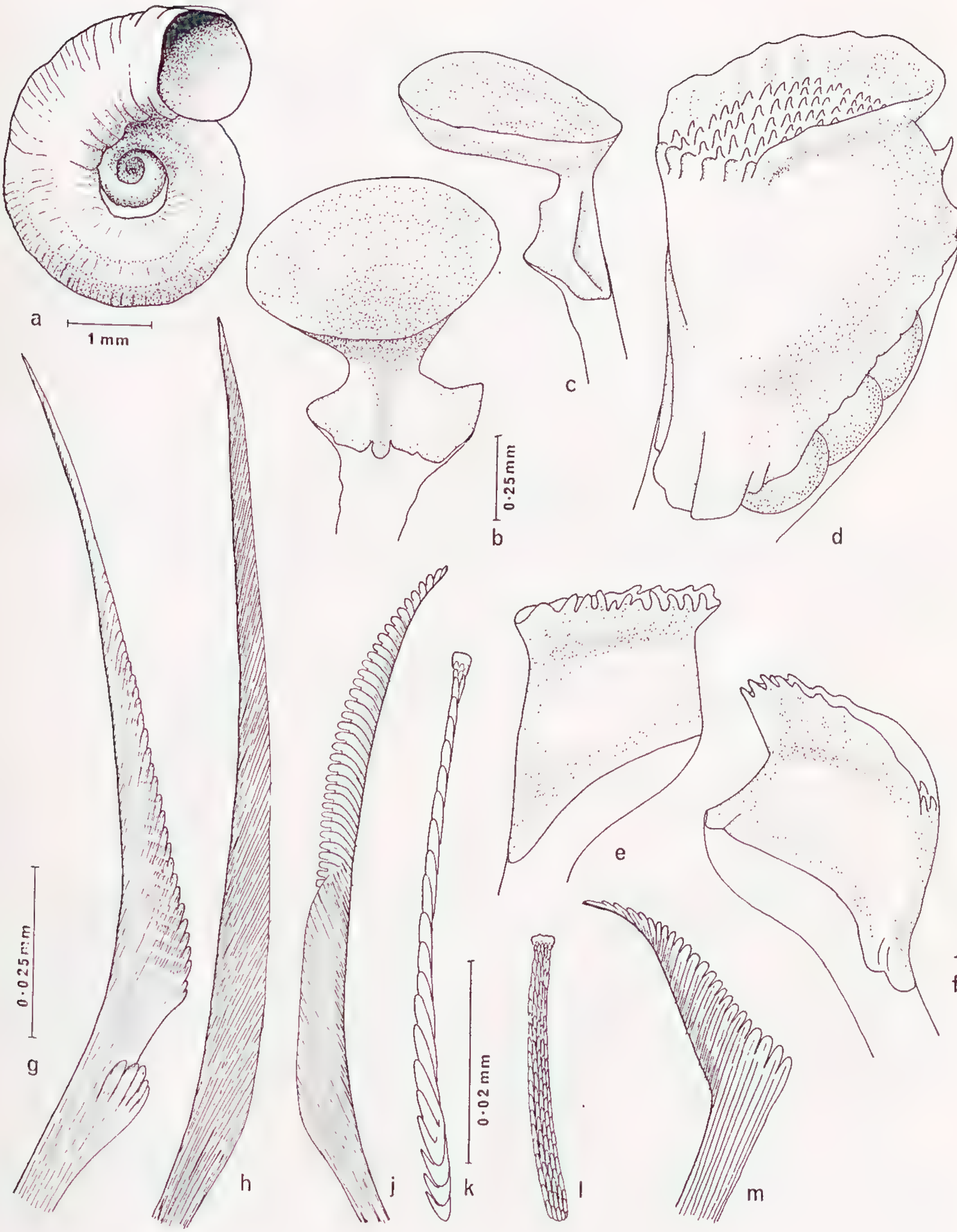

Figure 8.—*Pileolaria* (*Pileolaria*) *militaris:* a, tube; b and c, juvenile operculum, face and side views; d, typical adult operculum with embryos; e and f, variations of adult opercula; g, collar seta; h, simple seta of second or third fascicles; j, sickle seta from third fascicles; k, thoracic uncinus; l, abdominal uncinus; m, abdominal seta. Scales: c and d as b; e as f; h, j and m as g; l as k.

It is interesting to note that the "black spot", first described by Zibrowius (1967), is always found in the wide-spread populations of this species, but has not been found so far in other species, not even in closely related forms, such as *Pileolaria quasimilitaris* (Bailey, 1970). Several other species of *Pileolaria* have red or orange patches in this region, but these tend to disappear in preserved material.

Distribution

Very wide-spread on stones and algae in warm and temperate water. Zibrowius (1968) gives a comprehensive review of previous records from the Mediterranean, north coast of France, west coast of Spain, Madeira, Azores, Mexico, Suez, Zanzibar and Ceylon. It has also been found at Senegal (Sourie, 1954); Aegean (Bailey, 1969a); Red Sea (Vine, 1972); Hawaii (Vine, Bailey-Brock and Straughan, 1972); Malta, Plymouth (U.K.), south-west Ireland, West Indies, Mozambique and Cape Verde Is. (personal observations).

Subgenus **Simplicaria** Knight-Jones, 1973

Mature operculum somewhat helmet-shaped, but shallow, elliptical and bilaterally asymmetrical; sickle setae absent; otherwise like *Pileolaria sensu stricto.*

Type: Spirorbis pseudomilitaris Thiriot-Quiévreux (1965).

Pileolaria (**Simplicaria**) **pseudomilitaris** (Thiriot-Quiévreux)

Material

Australian Mus, W.4481.

Description

Tube sinistral, often irregularly coiled and with transverse growth rings which may meander to give an impression of faint longitudinal ridges (figs 9a and b).

Operculum. Plate of the juvenile form is asymmetrically concave with a small eccentric peg (fig. 9c). The mature operculum is an asymmetrical elliptical cap with a partially encircling distal rim which seems to be always absent on the side nearest the substratum. The rim is entire in a newly mature operculum (fig. 9f) but usually with serrations or papillae in older specimens (figs 9d and e). There may also be several spines within this rim.

Thorax. Collar setae with fin and blade with coarse serrations and cross-striations (fig. 9g). Capillary setae are also associated with these fascicles. The setae of the second and third fascicles are simple and slender, with almost smooth margins (figs 9h and j). There are no sickle setae. Two rows of tori. Each uncinus small and slender, the largest having a single row of teeth along most of its length and finer more numerous teeth just behind the blunt anterior peg (fig. 9m).

Abdomen. Length of asetigerous region about five times the distance between the 1st and 2nd abdominal tori. About seventeen abdominal segments. Each uncinus with a blunt anterior peg (fig. 9l). Setae have fairly long, obliquely geniculate blades with large blunt distal teeth (fig. 9k).

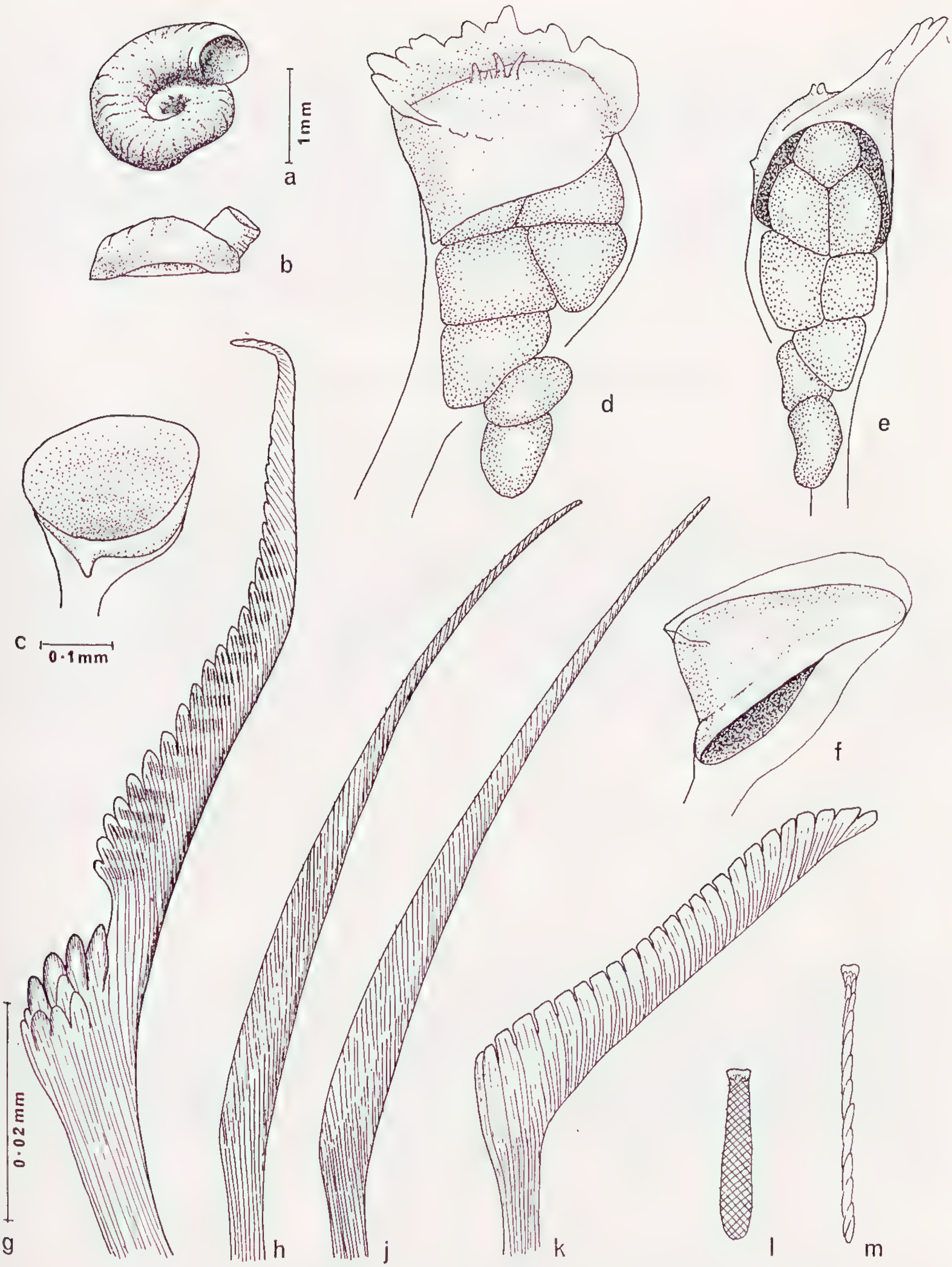

Figure 9.—*Pileolaria* (*Simplicaria*) *pseudomilitaris:* a, tube from above; b, tube, side view; c, juvenile operculum; d, typical adult operculum with embryos, side view; e, same, facing branchial crown; f, operculum of young adult; g, collar seta; h, seta of second fascicle; j, seta of third fascicle; k, abdominal seta; l, abdominal uncinus (cross-hatching represents rows of teeth too small to depict); m, thoracic uncinus. Scales: b as a; d, e and f as c; h to m as g.

Incubation

About eight to twelve eggs in the operculum. One specimen had apparently been fixed in the process of filling the operculum with eggs (figs 9d and e), assuming that this is done through a basal aperture, in the manner outlined by Potswald (1968) and Bailey (1969b). A perforation could be seen in the ampulla, facing a position between the centre of the branchial crown and the distal part of the dorsal groove (figs 9d and e). The eggs had not developed larval rudiments, so that it is unlikely that this specimen was releasing eggs, though there is no reason to suppose that the larvae are not released from the same position. Nevertheless, other specimens showed no sign of such an aperture, so it can be no more than transitory.

Locations

On stones and shells at Kangaroo Island and Sydney (table 1).

Remarks

This material agreed well with material from Malta, with Thiriot-Quiévreux's original description from southern France (1965) and with those of Bailey (1969a) from Chios and Harris (1968) from Naples. Harris called his material *Spirorbis berkeleyana* Rioja, but Rioja (1942) figured a mature operculum completely encircled by a distal rim and with the walls heavily calcified on one side but lightly calcified round the whole of the remaining periphery. This lies outside the range of variation in the different collections that we have examined. Another Galapagos form, *S. regalis* Bailey, is now considered to be synonymous with *P. pseudomilitaris* (Vine, Bailey-Brock & Straughan, 1972).

Distribution

Galapagos; Mediterranean (see above and also Zibrowius, 1968); Hawaii (Vine, Bailey-Brock and Straughan, 1972); New Zealand (Vine, 1974); Malta, Mozambique, Angola, Cape Verde Is. and Japan (personal observations).

Subgenus **Duplicaria** Vine, 1972

Opercula without distinct dimorphism between juveniles and adults, and may have two or more opercular plates stacked one above the other; embryos brooded in a lightly calcified cup below the opercular plates; collar setae not cross-striated; thoracic uncini may bear more than one longitudinal row of teeth for most of their lengths; the anterior abdominal torus on the concave side is often split into two unequal parts.

Type: Pileolaria (Duplicaria) koehleri (Caullery and Mesnil, 1897).

The type species has a world-wide distribution in warm waters and occurs on the Great Barrier Reef (Vine, personal communication) and New Zealand (Vine, 1974). It could well extend to south-eastern Australia, but was not found in our material. The tube has three irregular ridges, the outer of which is peripheral. Opercular plates (two or three) tend to stack and are joined to one another by a peripheral winged talon, the proximal point of which fits into a socket in the plate below. When brooding, the eggs lie between the lower plate and a delicate, slightly opaque proximal "cup". A good description was given by Bailey (1969a).

Genus **Amplaria** Knight-Jones, 1973

Sinistral coiling; concave side of thorax bears four tori and four fascicles of setae, convex side bears three tori and five fascicles; incubation in the operculum; fin and blade collar setae without cross-striations; sickle setae present in the third, fourth and fifth fascicles; thoracic uncini slender and with blunt anterior peg; abdominal setae geniculate, less than a quarter the size of the collar setae, with a prominent indentation at the "heel" and with short tapering blades; abdominal uncini somewhat asymmetrical in bilateral distribution with the largest tori about halfway along the setigerous region of the abdomen.

Type: Amplaria spiculosa Knight-Jones, 1973.

Amplaria spiculosa Knight-Jones

Material

British Mus. (Nat. Hist.) holotype 1971:16.

Description

The tube is somewhat square in cross section on account of two peripheral longitudinal ridges (fig. 2h). The opercular plate has a peripheral depression, which forms a sharp "V". It is encircled by a high transparent collar, the distal edge of which may be yellow and perhaps horny. From the centre of the plate arises a strong, slender, horny and somewhat hooked spine. The incubatory chamber below the plate is lightly calcified, with faint longitudinal granulations through which the embryos can be seen. The base of the chamber is formed by a calcified "cup". Vine (1974) has recently found this species in New Zealand.

Location

Kangaroo Island on stone (table 1).

Genus **Janua** Saint-Joseph, 1894, amended

Mostly with dextral coiling (pp 141 & 142); incubation in an opercular brood chamber below which a secondary plate (rudiment of the next opercular plate) is formed soon after spawning; only two pairs of thoracic tori; collar setae without a toothed fin; abdominal setae have elongated blades, as big as or more usually bigger than those of the collar setae (fig. 6f), and are often accompanied by secondary setae, with rudimentary shafts (Vine, 1972); thoracic uncini with anterior pegs narrow and more or less pointed in surface view; a bilaterally symmetrical distribution of abdominal tori (fig. 6e), the largest of which lie in the anterior half of the setigerous region; larvae have paired white attachment glands in the thoracic region.

Subgenus **Janua** Saint-Joseph, 1894

Dextral coiling; sickle setae present in the third thoracic fascicles; collar not forming a tunnel dorsally.

Type: Spirorbis pagenstecheri Quatrefages (1865) = *Spirorbis pusillus* St. Joseph, 1894 and *Spirorbis pusilloides* Bush, 1904.

Janua (Janua) pagenstecheri (Quatrefages)

Material

Australian Mus. W.4482.

Description

Tube usually coiled in one plane, with a single median longitudinal ridge in small specimens and up to three in larger ones; the median ridge being the most prominent. The outside of the coil may bear a large flange spreading over the substratum and extending to a position a little in front of the aperture (fig. 10a).

Opercular plate in the juvenile form is fairly flat and rather transparent except for an eccentric lightly calcified "disc" below which extends an almost peripheral peg-like talon (fig. 10b). On reaching maturity embryos are incubated below the plate and can be seen through the swollen walls of the ampulla. A secondary plate develops below the embryos which eventually becomes the distal plate of the next brood chamber. This and subsequent plates seem to lack talons (fig. 10c). They are usually slightly convex, with the highest point towards the edge where the talon used to be, but there is often a central depression. Fig. 10d shows the typical appearance at this stage, but the eccentric peak may be more prominent.

Thorax. Collar setae simple with finely serrate margins (fig. 10e) and accompanied by capillary setae. The setae of the second and third fascicles are simple, slender and rather straight, with almost smooth margins (fig. 10f). Sickle setae are also present in the third fascicles (fig. 10g). Uncini with about five rows of longitudinal teeth and a pointed anterior peg (fig. 10k).

Abdomen. The length of the asetigerous region is about three times the distance between the 1st and 2nd abdominal tori. There are about five setigers. Uncini with a broad fluted anterior peg (fig. 10l). Setae with long slender obliquely geniculate blades (fig. 10h). Their shafts may be accompanied by the blades of secondary setae (fig. 10j).

Incubation

About eight embryos in the operculum.

Locations

On stones and shells south-west of Kangaroo Island (table 1).

Remarks

Although the type species, this is in fact atypical of most species of *Janua*, which fall within the next subgenus. Previous descriptions contain some noteworthy anomalies. The collar setae, for instance, were said to have proximal fins (Caullery and Mesnil, 1897; Rioja, 1923; Fauvel, 1927; Gee, 1964; Bailey, 1969b) but Zibrowius (1968) found no such fins and examination of numerous mounted specimens from U.K., France, Chios and Malta, has tended to confirm his observations. Occasionally, however, a seta may be found to show the proximal differentiation seen in the figures of some of the above authors. A few specimens of *J.* (*J.*) *pagenstecheri* were viewed by stereoscan electronmicroscopy and the "blades" of the collar setae were shown to be, as in most Spirorbinae, subcircular in cross section and tapering distally. One seta, however, was rather bulbous proximally (fig. 10n) and a three-quarter view of this gives the appearance of an indented "margin" (fig. 10m). The "blades" are composed of numerous rods which show as fine teeth in profile. These are slightly larger on the proximal part of the blade than on the distal part, but there

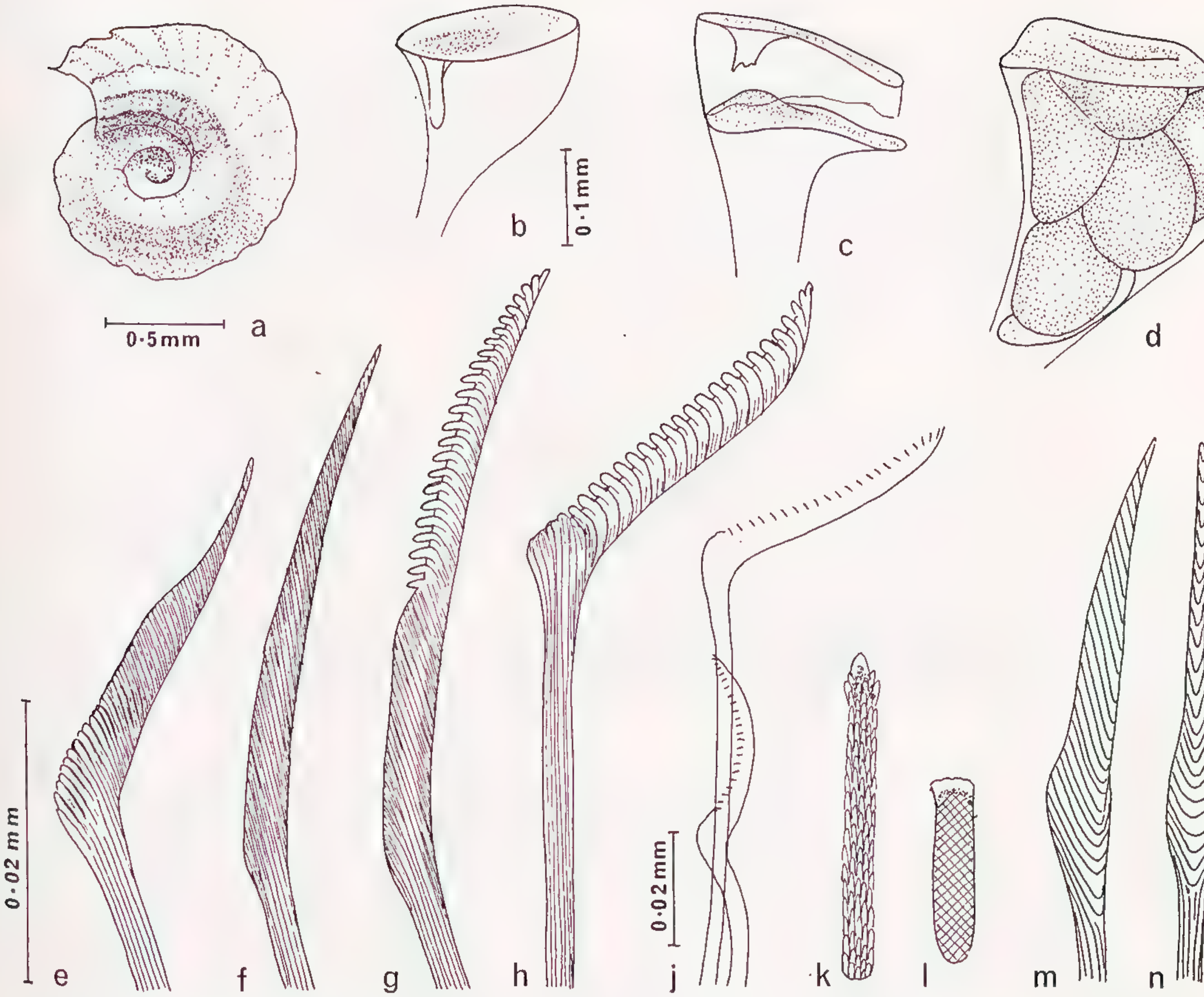

Figure 10.—*Janua* (*Janua*) *pagenstecheri:* a, tube; b, juvenile operculum, side view; c, adult operculum developing below damaged juvenile operculum; d, adult operculum with embryos; e, collar seta; f, simple seta from second or third fascicles; g, sickle seta from third fascicle; h, abdominal seta; j, secondary seta developing alongside shaft of a typical abdominal seta; k, thoracic uncinus; l, abdominal uncinus (cross-hatching denotes rows of longitudinal teeth too small to depict); m, diagrammatic drawing of a collar seta in three-quarter view, as it appears in a stereoscan electron micrograph; n, same showing view of the concave "edge". Scales: c and d as b; f to h and k to n as e.

is a zone of gradual transition between the two sizes. The appearance of a "fin" in some polyvinyl-lactophenol mounts may be due merely to individual setae being viewed at such an angle as to emphasise, in partial profile, any swelling of the proximal region. Zibrowius (1968) also comments on the occurrence at Marseille of specimens in which the opercula are without talons and markedly convex. Our examinations of Mediterranean and Australian forms confirm this, though we find that the strongly convex form is comparatively rare in populations from south-west Britain. Perhaps it is associated with warmer waters, more frequent breeding and therefore more frequent opercular moults. Thus we would agree with Vine, Bailey-Brock and Straughan (1972) that "*Spirorbis*" *epichysis* Bailey (1970) from the West Indies is probably synonymous with this species. Indeed, the range of opercular variation of *J.* (*J.*) *pagenstecheri* also includes *J.* (*J.*) *gnomonicus* (Bailey, 1969a) from the Aegean.

Distribution

Zibrowius (1968) has reviewed records of this species (including '*pusilloides*') from the Mediterranean, north and West Europe, Madeira, Canary Islands, Cape Verde Islands, Brazil, west coast of North America, Mexico, Tuamotu Islands, Gambia and the Persian Gulf. Other records are from Senegal (Sourie, 1954); Ceylon (de Silva, 1961); Galapagos Islands (Bailey and Harris, 1968); Aegean (as *Spirorbis gnomonicus* Bailey, 1969a); West Indies (as *Spirorbis epichysis* Bailey, 1970); Hawaii (Vine, Bailey-Brock, Straughan, 1972); New Zealand (Vine, 1974); South Africa and Angola (personal observations).

Subgenus **Dexiospira** Caullery and Mesnil 1897, amended

=*Neodexiospira* Pillai, 1970; see Knight-Jones, 1972. Coiling usually dextral; margins of the collar fused to form a tunnel over the mid-dorsal thoracic groove; sickle setae absent.

Type: Spirorbis pseudocorrugatus Bush (1904) *nom. nov. pro Spirorbis corrugatus* Caullery and Mesnil 1897 and most recent authors, *non* Montagu 1803, *non* Langerhans 1880 (see Knight-Jones, 1972 and 1973).

Janua (**Dexiospira**) **pseudocorrugata** (Bush)

Material

Australian Mus. W.4483.

Description

Tube dextral, with up to three ridges (the median one most prominent), either coiled flat against the substratum with a peripheral sloping flange extending to a position a little in front of the aperture (figs 11a and b), or with the last whorl ascending and round in cross-section. *Opercular plate* of juvenile flat or concave, often oblique and with a rather flat peripheral talon that may be somewhat triangular with a terminal cleft (fig. 11c, d), or subquadrangular in shape (fig. 11e, f). Specimens about to breed develop below the plate a transparent cylindrical chamber, which is very lightly calcified. Closely spaced granules may be seen in longitudinal rows on the calcified wall (fig. 11g), particularly when the chamber is empty and embryos do not obstruct the light. A secondary plate develops below the embryos and this eventually becomes the distal plate of the next chamber. This and subsequent plates are concave and do not bear talons (fig. 11h).

Thorax. Collar setae simple. Those of the convex side are fairly coarsely serrated with about six teeth and cross-striations per 8μ (fig. 11j). The cross-striations are more distinct in face view than in the more usual view from the side. The collar setae of the concave side have almost smooth margins and thus no cross-striations (fig. 11k), resembling those of the second and third fascicles (fig. 11l). Capillary setae are present in all fascicles. Uncini five to six teeth wide, each bearing a single pointed anterior peg (fig. 11n).

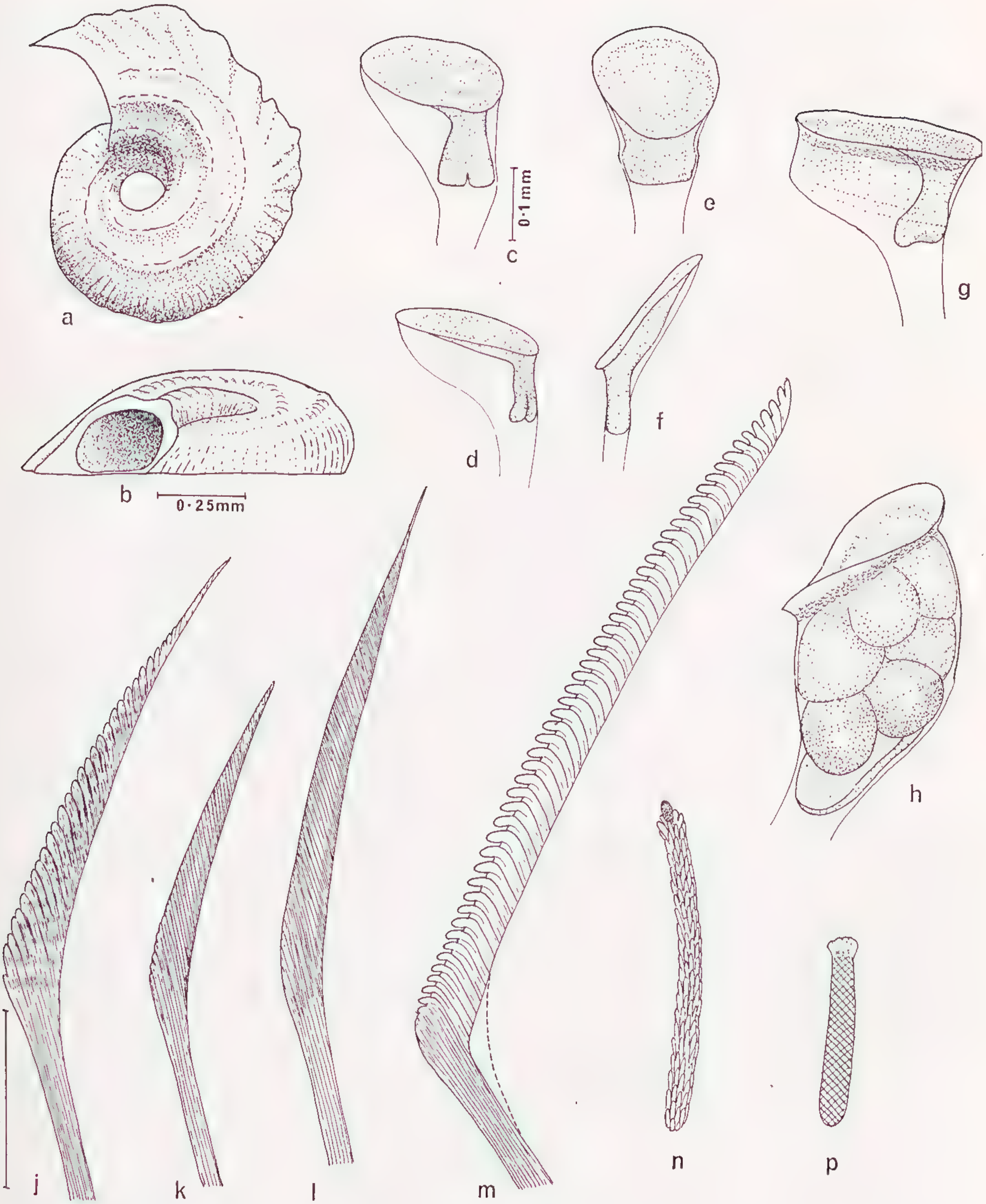

Figure 11.—*Janua* (*Dexiospira*) *pseudocorrugata* var. *ainu:* a, tube from above; b, tube from side; c, d, e and f, juvenile opercula, d and f side views of c and e; g, adolescent operculum with developing brood chamber; h, adult operculum; j, collar seta of convex side; k, collar seta of concave side; l, seta from second or third fascicles; m, abdominal seta (the dotted line represents the widening of the shaft found in *J.* (*D.*) *pseudocorrugata* from the type locality); n, thoracic uncinus; p, abdominal uncinus (cross-hatching represents rows of teeth too small to depict). Scales: a as b; d to h as c; k to p as j.

Abdomen. Asetigerous region fairly long (about five times the distance between the 1st and 2nd abdominal tori) and followed by about ten setigers. Uncini with a broad fluted anterior peg (fig. 11p). Blades of the setae obliquely geniculate and very long and slender (fig. 11m). The length/breadth ratio of the largest can be up to about 13:1. Blades of secondary setae may be found lying along the shafts of these setae.

Incubation

About eight embryos in the operculum.

Locations

On stones near Sydney and more sparsely at Kangaroo Island (table 1).

Remarks

This species shows considerable variation in the shape of the talon (Zibrowius, 1968), which is generally like a flattened pin in material found on algae in regions near the type locality (NW. France). The original description (Caullery and Mesnil, 1897) lacked any figure but could well apply to material with a slender talon, as in some that we have examined from SW. England, SW. Ireland, Roscoff and Malta, and in some Spanish and Mediterranean material figured by Rioja (1923), Sterzinger (1910) and Harris (1969). The somewhat triangular form (fig. 11c) is found particularly commonly on both stones or algae in the Mediterranean, West Indies, Hawaii (Zibrowius, 1968; Bailey, 1969 and 1970; Vine, Bailey-Brock and Straughan, 1972), Portugal, Corsica, Malta, Mozambique and Japan (personal observations). The subquadrangular form figured by Bailey (1969a) is also represented in material from Australia (fig. 11e) and particularly from Japan (kindly sent by Dr Tatuo Kawahara). Uchida (1971) describes a similar talon in a Japanese species which he named *Dexiospira ainu*, but we cannot clearly separate this from *J.* (*D.*) *pseudocorrugata*. The only difference which we can find is that the Australian and Japanese material has abdominal setae with shafts that do not widen noticeably towards the "heel", as they do in specimens from other locations (see fig. 11m). This does not seem enough to separate species, but it may be useful to regard the Australian material as *J.* (*D.*) *pseudocorrugata* var. *ainu*. Paratypes of *Neodexiospira mannarensis* Pillai and *N. benhami* Pillai (1970) from Ceylon were examined and are considered to be indistinguishable from this species, the abdominal setae having broad heels unlike those of var. *ainu*.

Zibrowius (1968) suggests that four other species may be conspecific with *J.* (*D.*) *pseudocorrugata*. They are indeed closely related and most are discussed later.

Distribution

Zibrowius (1968) also reviewed previous records of *J.* (*D.*) *pseudocorrugata* (as *Spirorbis corrugatus*) from France, Spain, Morocco, Azores, Mexico, Suez and various Mediterranean locations. However, the records from the open Atlantic (Fauvel, 1914) and from Madeira (Langerhans, 1880) are now considered to be species other than *J.* (*D.*) *pseudocorrugata* (Knight-Jones, 1972 and 1973). Other records: Naples (Harris, 1968), Aegean and W. Indies (Bailey, 1969a and 1970), Japan (as *Dexiospira ainu*, Uchida, 1971), Hawaii (Vine, Bailey-Brock and Straughan, 1972), SW. England and SW. Ireland, Corsica, Malta, Portugal, Mozambique and Japan (personal observations).

Janua (**Dexiospira**) **fenestrata** Knight-Jones, 1973

Material

British Mus. (Nat. Hist.) holotype 1971:17, paratypes 1971:18; Australian Mus. paratypes W.4477.

Description

Tube may coil in one plane or the last whorl may ascend. Three very prominent longitudinal ridges, the outer of which is peripheral and projects as far as, or beyond the area of attachment to the substratum. Between the ridges are deep transverse furrows, which in many specimens extend to form holes (tunnels) through the two outer ridges, giving a "lacy" appearance from above (fig. 3d).

Opercular plate has a central calcified disc surrounded by an upturned brown rather membranous rim. A cylindrical talon, bulbous and bilobed terminally, extends proximally from the dorsal edge of the plate (fig. 3d). Mature opercula which may not bear talons, develop calcified walls through which the embryos can be seen.

Collar setae on the concave side have simple blades with margins coarsely serrated (about four teeth and cross-striations per 8μ). Those of the convex side have almost smooth margins and thus no cross-striations. The asetigerous region was originally described as being remarkably long, but this is not typical of this species.

Location

Known only from rocks and *Ecklonia* holdfasts at Kangaroo Island (table 1). This species was separated mainly because of the sculpturing of the tube, but we now consider this to be a rather unreliable character. For instance, *J.* (*D.*) *nipponica* Okuda (1934) from Japan (kindly collected by Dr. Kawahara) may have ordinary tube ridges in certain habitats and very prominent perforated ridges in others. Nevertheless at Cape du Couedic *J.* (*D.*) *fenestrata* and its extremely close relative *J.* (*D.*) *pseudocorrugata* occurred together in circumstances indicating that the differences involved distinct strains and were not associated with differences in habitat or age. Besides the intricate sculpturing, the tubes of the former differ from most forms of *J.* (*D.*) *pseudocorrugata* in that the third ridge of the tube is always markedly peripheral (cf. figs 3d and c). Moreover *J.* (*D.*) *fenestrata* also differs from the Australian and Japanese form of *J.* (*D.*) *pseudocorrugata* in having the abdominal setae with shafts widening towards the "heel" at the base of the blade, although in this respect it resembles *J.* (*D.*) *pseudocorrugata* from other locations (see p. 134 and fig. 11m). The collar setae of the convex side, furthermore, have coarser serrations, resembling those of *J.* (*D.*) *lamellosa* and *J.* (*D.*) *steueri* rather than *J.* (*D.*) *pseudocorrugata* from any location.

These differences though constant are so slight that both the Australian forms may be no more than varieties of a basic stock of *J.* (*D.*) *pseudocorrugata*, which have nevertheless diverged sufficiently to remain separate from one another, at least on Kangaroo Island. They undoubtedly deserve further study.

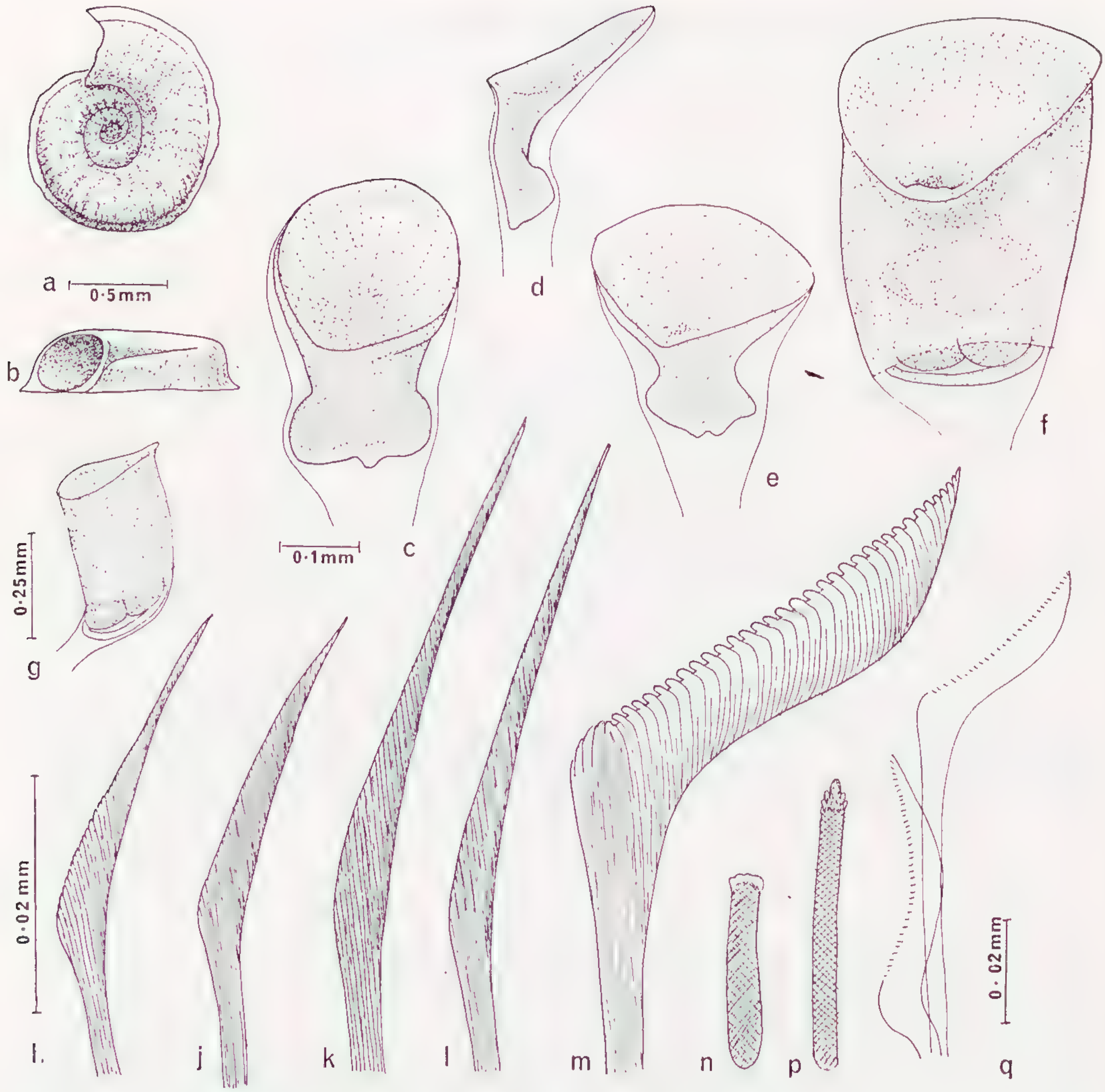

Figure 12.—*Janua* (*Dexiospira*) *formosa:* a, tube from above; b, same side view; c, d and e, juvenile opercula, d side view of c; f, operculum with brood chamber and embryos; g, fully adult operculum; h, collar seta of convex side; j, collar seta of concave side; k, seta of second fascicles; l, seta of the third fascicles; m, abdominal seta; n, abdominal uncinus (cross-hatching represents rows of teeth too small to depict); p, thoracic uncinus; q, secondary seta developing alongside shaft of a typical abdominal seta. Scales: b as a; d, e and f as c; j to p as h.

Janua (Dexiospira) formosa

Bush (1904) var. *australis*

Material

Australian Mus. W.4484.

Description

Tube dextral, rather round in cross section, with a very small peripheral flange and indistinct longitudinal ridges on the upper surface (figs 12a and b). Most of the tubes were very decalcified, making it difficult to study the range of variation.

Opercular plate asymmetrically concave, the deepest part closely associated with a flat winged talon (figs 12c, d, e, and f) which is usually faintly bifurcate terminally. Specimens about to breed develop a brood chamber, the walls of which are calcified heavily enough to hide the embryos but not the closely associated talon (fig. 12f). A secondary plate develops below the embryos and, as in the previous species, this and subsequent plates seem to lack talons (fig. 12g).

Thorax. Collar setae on both sides (figs 12h and j) resemble the setae of the second and third fascicles (figs 12k and l) in being simple with almost smooth margins and consequently without cross-striations. Uncini seem to have about ten longitudinal rows of fine teeth, with larger teeth bordering a pointed anterior peg (fig. 12p).

Abdomen. Asetigerous region long, about six times the distance between the 1st and 2nd abdominal tori. About ten setigers. Uncini with a broad fluted anterior peg (fig. 12n). Setae with obliquely geniculate blades, which are unusually wide, the length/breadth ratio being about 4.5:1 (fig. 12m). Blades of secondary setae may be found lying along the shafts in some fascicles (fig. 12q).

Incubation

About eight to ten embryos in the operculum.

Location

On *Ecklonia radiata* near Sydney (table 1).

Remarks

The talon of this Australian form may resemble that of *J.* (*D.*) *pseudocorrugata* (cf. figs 11c and 12c) and in these waters to a lesser degree that of *J.* (*D.*) *steueri* (fig. 14c). The collar setae and the abdominal setae, however, are distinct from both these species. The bilateral asymmetry of the concave plate is characteristic, but differs somewhat from material of *J.* (*D.*) *formosa* identified by Bush from Bermuda (kindly loaned by the Smithsonian Institute) and that from Kenya, West Indies and Ceylon (Knight-Jones 1972), in which (1) the concavity of the plate is situated more symmetrically, (2) the terminal lobes of the talon are longer and more like those of *J.* (*D.*) *steueri* from most locations (p. 141) and (3) the longitudinal rows of teeth on the thoracic uncini seem to be only about 6 or 7 instead of 10. Details of the setae, particularly the distinctive shape of the abdominal setae, are similar in all locations. We regard the Australian material as *J.* (*D.*) *formosa*, but tentatively separate it from the type by naming it var. *australis*.

Distribution

Bermuda (Bush, 1904, 1910); Ceylon, Kenya, West Indies and on floating *Sargassum* at two locations between U.S.A. and Bermuda (Knight-Jones, 1972); Mozambique (personal observations).

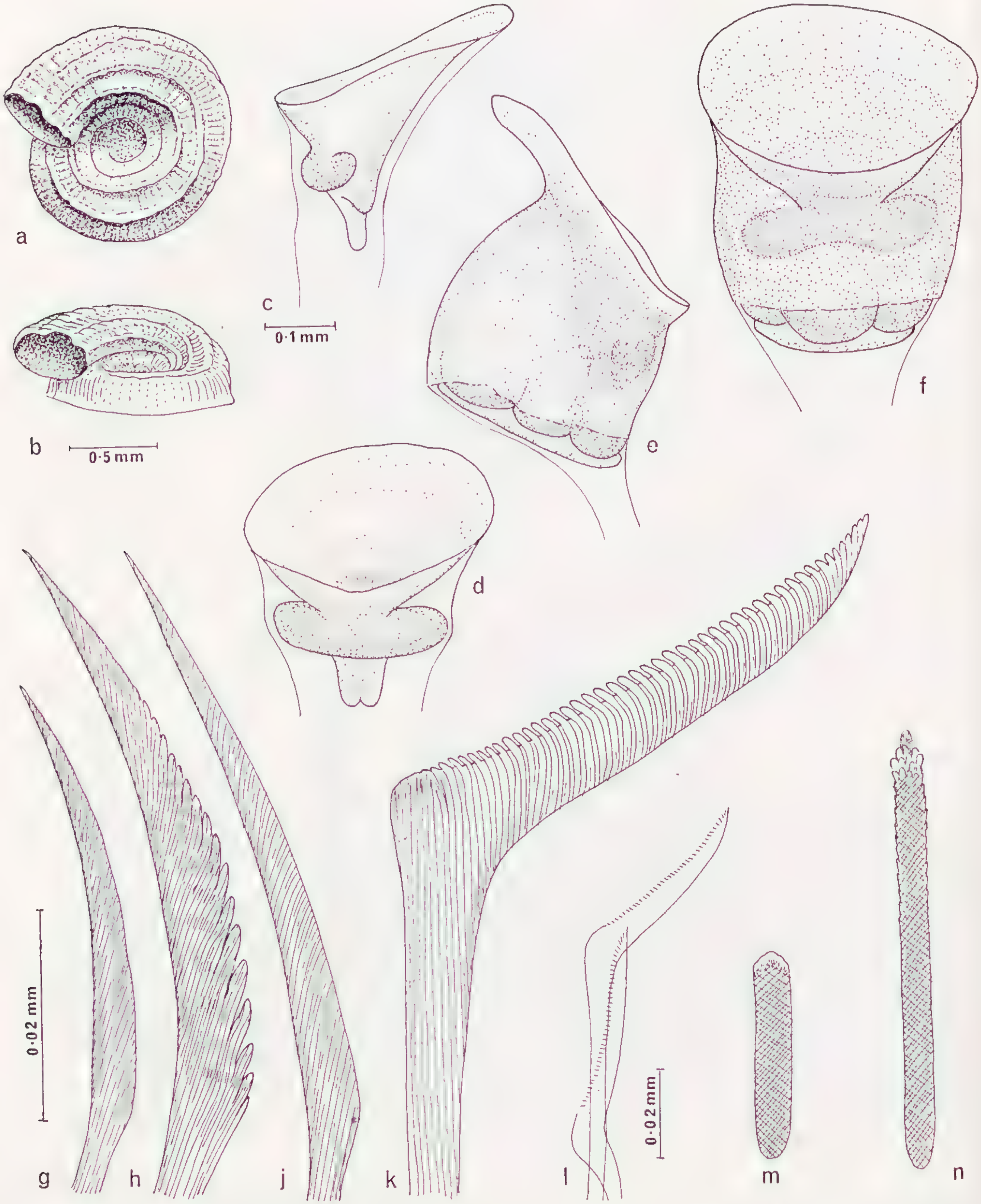

Figure 13.—*Janua* (*Dexiospira*) *lamellosa:* a, tube from above; b, same side view; c, juvenile operculum from side; d, same facing away from branchial crown; e and f, side and face views of an operculum with brood chamber and embryos; g, collar seta from concave side; h, collar seta from convex side; j, seta of second or third fascicles; k, abdominal seta; l, secondary seta developing alongside partner, which is a typical abdominal seta; m, abdominal uncinus; n, thoracic uncinus (cross-hatching represents rows of teeth too small to depict). Scales: a as b; d to f as c; h to k, m and n as g.

Janua (Dexiospira) lamellosa Lamark, 1818 (Wisely, 1962)

Material

Australian Mus. W.3751.

Description

Tube dextrally coiled, rather round in cross section, but with three or four distinct longitudinal ridges between which are fine transverse furrows (figs 13a and b).

Opercular plate funnel-shaped and bilaterally symmetrical. The dorso-dextral face of the funnel bears a large transverse rounded bar, the ends of which form bulbous lateral lobes. A small bilobed talon extends proximally from the apex of the "funnel" (figs 13c and d). A brood chamber develops in such a way that the plate forms a markedly projecting rim opposite the talon complex (fig. 13e). The chamber walls are heavily calcified, but the more opaque transverse bar can still be seen, though the terminal part of the talon may be obscured by embryos (figs 13e and f).

Thorax. Collar setae simple, those of the convex side coarsely serrated, with about three teeth (or cross-striations) per 8μ (fig. 13h), whilst those on the concave side have almost smooth margins and thus no cross-striations (fig. 13g) and are similar to those of the second and third fascicles (fig. 13j) Uncini seem to have about 8 longitudinal rows of teeth of which the anterior ones are larger and border a pointed anterior peg (fig. 13n).

Abdomen. A fairly long asetigerous region, followed by about eleven setigers (fig. 6e). Uncini with a rounded scalloped anterior peg (fig. 13m). Setae with long, fairly broad, obliquely geniculate blades (fig. 13k). Blades of secondary setae are sometimes found lying along the shafts of these setae (fig. 13l).

Incubation

About eight embryos in the operculum.

Location

On the marine angiosperm *Amphibolis antarctica* at Brighton, near Adelaide (table 1).

Distribution and remarks

Lamarck erected this species merely on the form of the tube (1818), which Chenu figured at a later date (1843). The type locality in Australia is unknown. Wisely (1962) gave the first adequate description of this species, basing his identification on Chenu's figure, which agrees very well with ours, though it must be admitted that such tube characters are not very distinctive. Our Australian material also agrees with Wisely's specimens from *Posidonia* sp., Port Hacking, which had been deposited in and were kindly loaned by the British Museum (Nat. Hist.). The slit in the operculum mentioned by Wisely would appear to be the line of dehiscence during release of embryos. We did not find a brood-chamber without a talon, though secondary plates showed no sign of developing talons. It seems to be very unusual amongst *Dexiospira* species, however, for late stage opercular plates to bear talons.

This species is probably closest to the Japanese form *J.* (*D.*) *foraminosa* (Moore & Bush, 1904), the proportions of the abdominal setae being very similar. It differs from that species in having a prominent cross-bar to the talon, a less slender and more opaque brood chamber and larger marginal teeth (coarser cross-striations) on the collar setae. It may well be endemic to Australia.

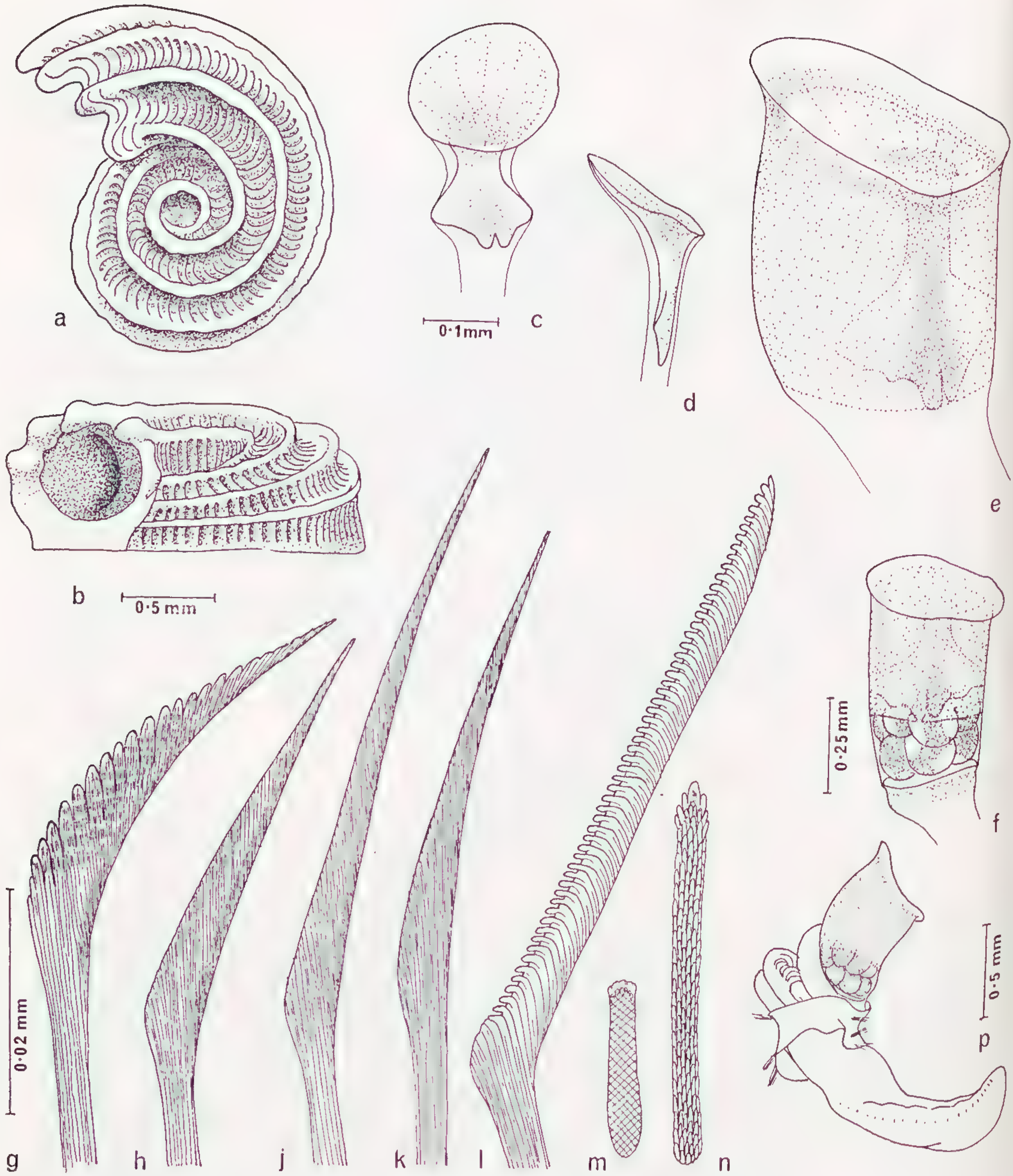

Figure 14.—*Janua* (*Dexiospira*) *steueri*: a, tube from above; b, same side view; c, juvenile operculum showing face of talon; d, same showing side; e, operculum with developing brood chamber; f, operculum with embryos, showing an adult brood chamber developing beneath the secondary plate; g, collar seta from convex side; h, collar seta from concave side; j, seta of second fascicles; k, seta of third fascicles; l, abdominal seta; m, abdominal uncinus (cross-hatching represents rows of teeth too small to depict); n, thoracic uncinus; p, whole animal showing adult operculum and collar margins fused over the dorsal groove. Scales: a as b; d and e as c; h to n as g.

Janua (Dexiospira) steueri (Sterzinger, 1909)

Material

Australian Mus. W.4485.

Description

Tube dextrally coiled, thick walled, with up to four rough prominent longitudinal ridges which usually terminate as three projections at the aperture. Between the ridges are fine curved transverse furrows (figs 14a and b).

Opercular plate slightly concave, bilaterally symmetrical, and bearing towards the dextro-dorsal edge a long talon, with flat transparent angular lateral wings and two white flat terminal lobes (figs 14c and d). A calcified chamber develops beneath the plate leaving a distal collar-like rim. The more opaque parts of the talon can be seen through the wall of the chamber (figs 14e and f). A secondary plate develops below the embryos and later chambers seem to lack talons (fig. 14p).

Thorax. Collar setae simple, those of the convex side coarsely serrated, with about four teeth (and cross-striations) per 8μ (fig. 14g), whilst those on the concave side have almost smooth margins and no cross-striations (fig. 14h) and are similar to those of the second and third fascicles (figs 14j and k). Uncini with about six longitudinal rows of teeth, of which the anterior ones are larger and flank a pointed anterior peg (fig. 14n).

Abdomen. Asetigerous region fairly long, about seven times the distance between the first and second abdominal tori, followed by about eleven setigera. Uncini with a blunt fluted anterior peg (fig. 14m). Setae with long and very slender obliquely geniculate blades (fig. 14l). Blades of secondary setae are sometimes found lying along the shafts of these setae.

Incubation

About 1–14 embryos in the operculum.

Location

On various algae (table 1) in the Adelaide and Kangaroo Island regions.

Remarks

The similarity between this and *J.* (*D.*) *formosa* (p. 136) is superficial and certain identification can be made by examining the collar setae and abdominal setae (cf. figs 12 and 14). Sterzinger's discovery of both sinistral and dextral forms of *J.* (*D.*) *steueri* (on both algae and stones) has been confirmed by recent collections from the Red Sea (Vine, 1972), but the Australian specimens that we have examined have all been dextral.

This species is particularly closely related to *J.* (*D.*) *pseudocorrugata*, but differs in being larger, with a more intricately sculptured tube, a brood chamber with more opaque walls and a more prominent distal rim, a talon with lateral wings and terminal pointed lobes and collar setae that are somewhat more coarsely serrated (cf. figs 11 and 14). "*Spirorbis*" *treadwelli* Pillai (1965) is probably the mature form of this species (Knight-Jones 1972), particularly because of the coarseness of the serrations of the collar setae.

Distribution

Suez (Sterzinger, 1909); West Indies (Bailey, 1970); Philippines (as *S. treadwelli*, Pillai, 1965); E. Australia (as *S. treadwelli*, Straughan, 1967); Kenya (Knight-Jones, 1972); Hawaii (Vine, Bailey-Brock and Straughan, 1972); Red Sea (Vine, 1972); New Zealand (Vine, 1974); Mozambique (personal observations);

Subgenus **Pillaiospira** Knight-Jones (1973)

Lacking sickle setae and in other respects too like *Dexiospira*, but with collar folds not fused dorsally.

Type: Janua (Pillaiospira) trifurcata Knight-Jones (1973).

Janua (Pillaiospira) trifurcata Knight-Jones

Material

British Mus. (Nat. Hist.) holotype 1971:19, paratypes 1971:20; Australian Mus. paratypes W.4478.

Description

Tube dextral, the last whorl usually coiling over the previous whorls, round in cross section and bearing three longitudinal ridges, with "chevron" sculpturing between (fig. 3b).

Opercular plate in juvenile specimens (fig. 3b) is convex with the dextro-dorsal edge folded downwards to form a deep U-shaped depression, with which a flattened "peg" talon is associated. The folding is asymmetrical and flanked on the right side by a peripheral protrusion. When the first incubatory chamber is formed, by the development of finely granular calcified walls, it is as wide as or wider than the plate, so there is no protruding distal rim. A secondary plate develops below the embryos and forms the distal part of the next brood chamber. This chamber lacks a talon and is more symmetrical, with a flat distal plate surrounded by a thick undulating rim. The wall of an empty chamber in reflected light shows widely spaced longitudinal markings. When damaged the chamber tends to break in the position of these markings, which seem to be lines of weakness, from which the intervening sections of wall splay out like the staves of a barrel.

Thorax. The collar setae of both fascicles are simple with almost smooth margins and no cross-striations. The uncini are distinctive in having a dense strongly trifurcate anterior peg and about 5 longitudinal rows of teeth.

Locations

Adelaide and Kangaroo Island, on algae (Table 1).

Subgenus **Fauveldora** Knight-Jones 1972

As for *Dexiospira*, but with sinistral coiling.

Type: Janua (Fauveldora) kayi Knight-Jones (1972).

The type was found off Kenya. Its talon resembles that of *J. (D.) steueri*, but the distal plate is strongly domed. *J. (F.) anticorrugata* Vine (1972), the only other species in this subgenus, occurs in the Red Sea. Its talon resembles that of *J. (D.) pseudocorrugata*. Neither of these species of *Fauveldora* have yet been found in Australian waters and they are likely to be confined to tropical latitudes. Both species have collar setae (on both sides) with margins that are finely serrated and without cross-striations.

Subgenus **Leodora** Saint-Joseph (1894)

Sinistral coiling; thoracic collar folds unfused; sickle setae absent (see Vine, Bailey-Brock and Straughan, 1972).

Type: Spirorbis laevis Quatrefages (1865).

This species appears to be a *nomen nudum*. It was recorded by Ehlers (1913) at Simonstown, S. Africa (the only record in the southern hemisphere) but his material, deposited in the Hamburg museum, has proved on examination to be a dextral form,

in spite of Ehler's figure to the contrary (Zibrowius, 1973). This subgenus however includes another species *Janua* (*Leodora*) *knightjonesi* de Silva (1965) which has a widespread distribution in warm latitudes: Ceylon (de Silva, 1965); West Indies (Bailey, 1970); Hawaii (Vine, Bailey-Brock and Straughan, 1972); and Red Sea (Vine, 1972). This species has been found recently in the region of the Great Barrier Reef (Vine, personal communication). The tube has three well defined ridges. The operculum usually bears two and occasionally three brood chambers one above the other. The talon is peg-like as in *J.* (*J.*) *pagenstecheri*, but peculiar in that it is always developed in each of the successive chambers.

Genus **Anomalorbis** Vine (1972)

Tube probably dextral; rudiments of five thoracic segments; collar setae simple with smooth margins (no fins), resembling the setae of the other thoracic segments; sickle setae absent; development of embryos probably in the operculum.

Type: Anomalorbis manuatus Vine (1972).

Known from only a single specimen, collected from a depth of 30 metres near Port Sudan. It may possibly extend into the warmer waters of the southern hemisphere. The tube and operculum probably resemble those of the juvenile form of *J.* (*D.*) *steueri*. There are four tori and five fascicles of setae on the concave side and three tori and four fascicles on the convex side of the thorax. Each thoracic uncinus has a large pointed anterior peg and a number of associated finger-like projections, looking like the thumb and fingers of a hand. The number of longitudinal rows of teeth on a thoracic uncinus varies from one on the larger uncini of the convex side, to about five on the smaller uncini.

ECOLOGICAL NOTES

All the collections were made by L C L, at the localities listed in table 1. Parsley Bay, South Head, Vaucluse (33° 52′ S., 151° 17′ E.), visited 22 July 1967, is a narrow inlet with rocky sides, sheltered within the Sydney Heads. Five Spirorbinae were found at various levels between tidemarks, the most abundant being *Eulaeospira convexis* and *Janua formosa*, both from fronds of *Ecklonia*. The other species, of which the most common was *J. pseudocorrugata*, were scraped from stones and shells.

The remaining collections were made between 1 and 15 January, 1967. Brighton beach, Adelaide (35° 00′ S., 138° 28′ E.) is sandy without rocky outcrops, but there were plenty of Spirorbinae on plants floating in the surf. These had presumably been washed in from sublittoral reefs and they bore five species, of which the most abundant was *Metalaeospira tenuis*. Similar collections were made at Moanna, a sandy beach 24 miles south of Adelaide, from a large pile of algae probably washed in from a sublittoral reef. There were also Spirorbinae on *Sargassum* attached to rocks on the lower shore at Moanna (13 January, 1967), but these were not kept separate, in the collecting jar, from those that had been drifting.

The greatest variety of Spirorbinae was found on Kangaroo Island (35° 55′ S., 136° 58′ E.), where the exposure to wave action of various shores has been described thoroughly by Womersley (1947). Kingscote, on the sheltered north-east coast, was

Table 1

Distribution of species between site samples. M, L & U & S = middle, lower & upper shore & sublittoral respectively

Locality	Substratum	Tidal level	*E. convexis*	*M. tenuis*	*P. triflabellis*	*P. canina*	*R. quadricostalis*	*P. militaris*	*P. pseudomilitaris*	*A. spiculosa*	*J. pagenstecheri*	*J. pseudocorrugata*	*J. fenestrata*	*J. formosa*	*J. lamellosa*	*J. steueri*	*J. trifurcata*
Sydney,	Stones and molluscs	M	..	..	..	..	..	..	3+	..	..	25+	..	..	..	..	..
Parsley	Stones and molluscs	L	..	..	..	..	..	4	14	..	..	24	..	..	..	..	..
Bay	Stones and molluscs	S	..	..	..	..	..	..	6+	..	..	24+	..	..	..	..	..
	Ecklonia holdfasts	S	..	..	..	..	..	..	..	..	..	22	..	..	..	..	..
	Ecklonia fronds	L & S	100+	..	..	..	..	..	..	..	..	..	..	200+	..	..	..
	Sargassum	L & S	13	..	..	..	..	..	..	..	..	..	..	1	..	..	..
Adelaide,	*Amphibolis*	S	10	19	..	..	..	..	..	..	..	..	..	..	9	8	..
Brighton	*Jeannerettia*	S	4	200+	..	..	..	..	..	..	..	..	..	..	..	..	..
Beach	*Hypnea*	S	..	..	..	..	..	..	..	..	..	..	..	..	..	17	19
Moanna	*Sargassum*	S	19	40	..	..	..	..	..	..	..	..	..	..	..	50	..
Kingscote	Stones and molluscs	L	..	..	..	..	..	..	40	1	84	..	..	..	..	..	..
Sou-West	Stones	M	..	..	..	..	..	..	..	..	10	..	..	..	..	..	..
R.		L	..	..	3	6	..	..	..	..	20+	..	..	..	..	..	..
	Amphibolis	S	2	4	..	..	..	..	..	..	..	..	..	..	..	..	..
	Epiphyte on *Amphibolis*	S	..	..	..	..	28	..	..	..	..	..	..	..	..	..	..
	Hypnea	S	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9
	Sargassum	S	7	..	..	..	..	..	..	..	..	..	..	..	..	16	..
Cape du	Stones and rocks	U	..	..	6	..	..	38	..	..	..	..	1	..	..	..	..
Couedic	Stones	M & L	..	..	2	27	..	61	8	..	23	4	13	..	..	..	..
	Amphibolis	L	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
	Pterocladia	L	..	..	..	..	100+	..	..	..	..	..	..	..	..	..	..
	Ecklonia holdfasts	S	100+	..	6	..	4	..	..	..	..	..	1	..	..	4	..

visited on 3 Jan. The intertidal zone was searched and three species were scraped from loose rocks and mussels. Spirorbinae were common there, but generally confined to shaded under-surfaces. This collection included the extraordinary opercular incubator, *Amplaria spiculosa*, and the largest numbers of *Pileolaria pseudomilitaris* and *Janua pagenstecheri*.

The south coast of Kangaroo Island, which is very exposed to wave action, was sampled more intensively. At Sou-West River (visited 5 and 6 Jan.) three species were scraped from stones which were jammed under larger boulders and five more were found on unattached plants that had been washed up in heavy surf, apparently from a sublittoral reef about 100 metres off shore. At Cape du Couedic (visited 8 Jan.) eleven species were found, the most remarkable being *Romanchella quadricostalis*, attached to the alga *Pterocladia*, which formed a distinct zone on the shore. This was the sole locality for *Janua fenestrata* and the best for *Pileolaria militaris* and the two species of *Protolaeospira*.

Frequent exchanges of silt-free water undoubtedly favour most Spirorbinae, but it should not be supposed, from their abundance and variety at Cape du Couedic, that they are particularly favoured by exposure to wave action. Most of the collections there were taken from areas of local shelter, particularly in *Ecklonia* holdfasts and shore pools. Practically all species from pools, moreover, were scraped from the undersides of stones or rocky overhangs, whilst the *Romanchella* occurred on the more sheltered basal parts of *Pterocladia* plants. Littoral Spirorbinae generally do best where the sand-table is low and there is consequently less abrasion by wave-borne particles (Gee and Knight-Jones, 1962). They reach their greatest variety in cool latitudes, to judge from the number of species in New Zealand (Vine, 1974). Such factors probably contribute to the variety at Cape du Couedic.

The shore levels at which collections were made are indicated roughly in table 1. Most collections of stones and shells came from between tidemarks, where Spirorbinae were generally common, but confined to pools or damp and shady places. *Pileolaria militaris* seemed to be favoured by conditions in pools quite high on the shore at Cape du Couedic. One might expect this pantropical species to benefit from raised temperatures due to insolation of such pools, yet at Plymouth U.K. (latitude 50° N.) it seems to be confined to the sublittoral, presumably because of the harder winter conditions at higher latitudes. In many warm parts of the world the most generally abundant littoral species are *Pileolaria militaris*, *P. pseudomilitaris*, *Janua pagenstecheri* and *J. pseudocorrugata*.

To judge from experience elsewhere, several more Australian Spirorbinae could be discovered by collecting stones and bryozoa from rocky sublittoral areas, particularly off the southern coasts. In our collections *Janua lamellosa*, *J. steueri* and *J. trifurcata* were found only on drifting plants, that had probably come from sublittoral situations. The other four species which were always attached to plants seemed to occur both sublittorally and at low levels between tidemarks. We thus found seven species which were invariably attached to plants, whilst six species seemed to shun them. Only two species, *Protolaeospira triflabellis* and *Janua fenestrata*, were found both on stones and on algae, and those algae were *Ecklonia* holdfasts, which offer a special environment, with more shelter and less mucus than algal fronds provide.

The species of plants providing substrata were kindly identified by Dr H. B. S. Womersley (table 2). Reference back to table 1 will show that choice by the settling larvae of most of these Spirorbinae cannot be highly specific. Only *Janua trifurcata* may perhaps be confined to a single alga, a species of *Hypnea*. This *Janua*, moreover,

Table 2

Marine plants bearing Spirorbinae (see also Table 1):

Angiospermae

Amphibolis antarctica (Labillardiere) Sonder & Aschers

Phaeophyceae

Ecklonia radiata (C. Agardh) J. Agardh

Sargassum linearifolium (Turner) C. Agardh

Rhodophyceae

Pterocladia capillacea (Gmelin) Bornet & Thuret

Erythroclonium angustatum Sonder

Hypnea musciformis (Wulfen) Lamouroux?

Spyridia biannulata J. Agardh

Polysiphonia cancellata Harvey

Jeannerettia pedicellata (Harvey) Papenfuss

Echinothamnion hystrix (Hooker & Harvey) Kylin

was sparse in our collections and may prove to favour other substrata too, when its main populations are found. Of the other species that may perhaps be endemic, *Janua lamellosa* and *Eulaeospira convexis* were originally described from a marine angiosperm at Port Hacking and occurred in our collections mostly on *Amphibolis*, an angiosperm referred until recently to *Cymodocea*. *E. convexis*, however, also occurred on a variety of algae and so did *Romanchella quadricostalis* and *Metalaeospira tenuis*, though the former particularly favoured *Pterocladia* and the latter *Jeanerettia*. Both the remaining species have been found throughout their geographical range mostly attached to plants. *Janua formosa*, indeed, is almost or entirely confined to plants (Knight-Jones, 1972), though *J. steueri* occurs on a variety of substrata in the Red Sea (Vine, 1972).

Of the other species, which were here confined to rocks and shells, *Pileolaria pseudomilitaris* is now known to have a wide distribution, but has never been recorded from plants, nor have any *Protolaeospira* species so far as we are aware, apart from a single record of *P. racemosa* on kelp holdfasts (Rioja, 1962). *Pileolaria militaris* and *Janua pseudocorrugata*, however, occur on plants in the Mediterranean and seem to be confined to algae in a few British localities where we have found them recently (Plymouth and south-west Ireland), whilst *J. pagenstecheri* occurs very commonly on British coastal algae. *Janua* species, indeed, are particularly abundant on algae, probably because they are small and have short life cycles which would fit them to colonise ephemeral substrata.

ZOOGEOGRAPHICAL COMPARISONS

Of the fifteen species found, six (both *Pileolaria* and all the non-endemic *Janua* species) are wide-spread in warm seas. Some of these often attach themselves to *Sargassum* and may thus drift great distances. Only *P. pseudomilitaris* seems invariably to shun algal substrata and this may perhaps be carried about by shipping.

If the general distributions of these six species are examined, it would appear that *Janua formosa* is particularly adapted to high temperatures, for it has not been recorded from the Mediterranean, Hawaii or New Zealand. *J. pagenstecheri*, in contrast, can tolerate a wide temperature range for it extends from Norway and New Zealand to tropical locations such as Brazil, Angola and Ceylon. The absence of *J. formosa* from the Adelaide area agrees with its distribution elsewhere, but it is surprising that *J. pagenstecheri* was not found at Parsley Bay.

Most species of the pantropical group were represented at Parsley Bay, however, and if we include the original description of *J. lamellosa* from Port Hacking it now appears that there are at least six species of Spirorbinae in the area of Sydney. Five of these are opercular incubators, helping to confirm that this method of brood protection is favoured where the water is warm (Bailey, 1969a; Harris, 1969). The remaining species, *Eulaeospira convexis*, may be endemic to Australia, but appears to represent an unusual genus of tube incubators, which is otherwise represented (so far as is certainly known) by a single tropical species (p. 120) originally described from Ceylon and now known from the Red Sea (Vine, 1972). This genus, however, would seem to have affinities with other tube-incubators of the southern hemisphere, to judge from the asymmetrical distribution of its abdominal uncini (fig. 6a; see also Knight-Jones, Knight-Jones and Bregazzi, 1973).

It may seem remarkable that the species links so far discovered, between the Spirorbinae of Australia and New Zealand, do not involve members of these southern genera. A recent study in New Zealand (Vine, 1974) has resulted in nineteen species being recorded from there, but these include only five of those described here and all five are opercular incubators. One is the extraordinary *Amplaria spiculosa*, whilst the others belong to the pantropical group mentioned above. The majority of New Zealand Spirorbinae, however, have southern affinities, only one being a species of *Spirorbis sensu stricto*. There are at least six *Protolaeospira*, one *Paralaeospira*, one *Metalaeospira* (close to *M. tenuis*), and two *Romanchella*, including at least three species links with Cape Horn and two with the Cape of Good Hope.

Since the Australian representatives of these genera are different from those known elsewhere, it seems unlikely that their spread around the southern hemisphere has been helped much by shipping. Some older dispersal agency must have been involved, such as the buoyant kelp plants which drift in the roaring forties, with epiphytes, stones and shells attached to their holdfasts. Considering the pattern of currents and land masses (fig. 1), it might be expected that species distributed in such a system would colonise New Zealand readily without divergent speciation, but would more rarely succeed in colonising Australia. Subantarctic organisms could be stranded on the south coast of New Zealand in water temperatures low enough for their easy establishment. Subsequent spread could take place gradually and could involve strains adapted to higher temperatures. There need be no sudden temperature change to constitute a barrier to further spreading or to gene flow. Tasmania, however, is north of the subtropical convergence and subantarctic organisms drifting there would meet a considerable increase in temperature. Only very occasionally would a temperature-tolerant strain be able to establish itself and such a strain would then tend to diverge into an endemic species, gene flow from the south being nil or negligible.

The biogeographical data available generally conform with this prediction. Considering the algae as a whole, it seems that the degree of endemism in South Australia is probably higher than in any other part of the world (Womersley, 1960). Drift plants of the buoyant fucacean *Durvillea antarctica* are recorded from the west coast of Tasmania, having presumably come from Kerguelen 3,000 miles away (Knox,

1963). Nevertheless this species does not become established in Australia, though it occurs in New Zealand at water temperatures higher than those in Tasmania (Womersley, 1960). *Durvillea potatorum*, however, is endemic to south-east Australia. Considering the Spirorbinae, those most likely to be transported on southern kelp would be *Paralaeospira levinseni* and *Romanchella perrieri*. Both are often found attached to algae and the ranges of both appear to agree with that of *Durvillea antarctica*, except that *Paralaeospira levinseni* also extends to South Africa, where we have seen it abundantly on *Ecklonia*. Careful search off South Africa, however, revealed no species of *Romanchella* or *Metalaeospira*. There again the subtropical convergence has probably been an effective barrier. It would now be interesting to search Tasmanian shores, for representatives of these southern genera other than the species recorded here, which seem likely to be endemic.

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Descriptions of Four New Damselfishes (Pomacentridae) from Papua New Guinea and Eastern Australia

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Plates 1–5 Manuscript received 7th December, 1972

ABSTRACT

Four new species of damselfishes, *Abudefduf whitleyi*, *A. flavipinnis*, *Pomacentrus australis*, and *P. pseudochrysopoecilus* are described. *A. whitleyi* from Queensland differs from its closest relatives, *A. saxatilis* and *A. notatus*, on the basis of colour pattern and a suborbital which is mostly naked. *A. flavipinnis* from New Guinea and the Great Barrier Reef is related to *A. cyaneus* but is separable on the basis of colour pattern and the soft dorsal ray count. *P. australis* from Queensland and New South Wales is characterized by an elongate body, blue coloration, and 14 dorsal spines. *P. pseudochrysopoecilus* from the D'Entrecasteaux Islands, Solomon Sea, and Queensland resembles its namesake, *P. chrysopoecilus*, but can be differentiated on the basis of colour pattern, gill raker count, and habitat preference.

INTRODUCTION

The present taxonomic knowledge of the Pomacentridae of the Indo-Australian Archipelago is due largely to the comprehensive foundation laid down by Pieter Bleeker (1877a and b), the Dutch surgeon-naturalist who collected and studied the fishes of this region over 100 years ago. More recently, significant contributions have been made by Montalban (1927), Fowler and Bean (1928), Whitley (1929), De Beaufort (1940), Marshall (1964), and Munro (1967). De Beaufort's work is the most comprehensive, listing 85 species of damselfishes from the archipelago. Our knowledge of the pomacentrids of this great faunal region remains inadequate, in spite of these investigations. The senior author is currently preparing a monograph of the Pomacentridae of New Guinea and Queensland which includes 111 species, thus representing a substantial increase in the known fauna. The present paper contains descriptions of four new species, including two *Abudefduf* and two

Pomacentrus. Many of the type specimens were collected by the senior author while conducting ichthyological investigations aboard Dr Walter A. Starck's research vessel *El Torito* during the first half of 1972. These collections were made along the northeast coast of Papua New Guinea and at the D'Entrecasteaux Islands, Egum Atoll (Solomon Sea), Osprey Reef (Coral Reef), and Pixie Reef (Great Barrier Reef). Further collections were made by the authors at the Capricorn Group, the southernmost islands of the Great Barrier Reef. Additional specimens were obtained from the Australian Museum, Sydney; of particular value were the large collections of fishes made by the Museum at One Tree Island, Capricorn Group between 1966 and 1972.

METHODS OF COUNTING AND MEASURING

The methods of counting and measuring are the same as those described in detail by Allen (1972) except the length of the dorsal and anal spines are measured proximally at the base of the spine rather than the point at which the spine emerges from the scaly sheath. Measurements were made with needlepoint dial calipers to the nearest millimetre (mm). Standard length is abbreviated as SL. When more than one paratype is listed an abbreviated style is used with the number of specimens followed by their size range (mm SL) in parentheses. The fraction $\frac{1}{2}$ appearing in the dorsal and anal fin ray formulae refers to a bifurcate condition of the last ray.

The counts and proportions which appear in parentheses under the description section for each species apply to the paratypes when differing from the holotype. A summary of counts for the dorsal, anal, and pectoral fin rays, gill rakers on the first arch and tubed lateral line scales are presented in Tables 1 and 2.

Type material has been deposited at the following institutions: Australian Museum, Sydney (AMS); Bernice P. Bishop Museum, Honolulu (BPBM); British Museum (Natural History), London (BMNH); Muséum National d'Histoire Naturelle, Paris (MNHN); Queensland Museum, Brisbane (QM); National Museum of Natural History, Washington, D.C. (USNM).

SPECIES ACCOUNTS

Abudefduf whitleyi n.sp.

(Plate 1; Table 3)

Holotype: AMS I.16634-001, 132 mm SL, Pixie Reef (16° 32′ S, 145° 51′ E), Great Barrier Reef, off Cairns, Queensland, Australia, 3 m, G. R. Allen, 2 July, 1972.

Paratypes: AMS IA.894, 1 (62), Hook Island, Whitsunday Passage, Queensland, Australia, E. H. Rainford, 1922; AMS IA.1772, 1 (94), Port Denison, Queensland, Australia, E. H. Rainford (no date); AMS IB.3112 1 (55), Green Island, off Cairns, Queensland, Australia, F. A. McNeill, 1953; AMS I.15638-007, 7 (106–128), One Tree Island, Capricorn Group, Great Barrier Reef, 5 m, explosives, F. H. Talbot and party, 6 October 1967; AMS I.15642-001, 10 (52–125), same data as AMS I.15638-007 except 4 m, 1 October 1968; AMS I.15681-004, 9 (93–119), same data as AMS I.15638-007 except 8 m, 25 November 1969; AMS I.15683-003, 67 (68–129), same data as AMS I.15638-007 except 4 m, 30 November 1969; BPBM, 13605, 3 (95–101), same data as AMS 15683-003; BPBM 13606, 1 (123), Fitzroy

Island, about 15 miles southeast of Cairns, Queensland, Australia, 3 m, multi-prong spear, G. R. Allen, 6 August 1972; USNM 207939, 1 (95), same data as AMS I.15638–007; USNM 207940, 2 (99), same data as AMS I.15683–003.

Diagnosis: A species of *Abudefduf* with the following combination of characters: dorsal spines usually 13; horizontal scale rows from base of dorsal fin to middle of lateral line (exclusive of small dorsal base sheath scales) 3 to 4; predorsal scales reaching to level of nostrils; preorbital and most of suborbital naked; inferior preopercular limb scaly; head and body usually uniformly dark in preservative (except for pale abdominal region), but with five narrow transverse dark bars on pale background when alive; caudal fin and most of soft dorsal and anal fin blackish when alive; caudal lobes pointed.

Description: The proportional measurements for the holotype and several paratypes are expressed as percentage of the SL in Table 3.

Dorsal rays XIII,13 (one paratype with XIV,13); anal rays II,12; pectoral rays 19 (19 to 20); pelvic rays I,5; branched caudal rays 13; gill rakers on the first arch 23 (22 to 24); tubed lateral line scales 22 (20 to 21); vertical scale rows from upper edge of gill opening to base of caudal fin 29 (28 to 29); horizontal scale rows from base of dorsal fin to middle of lateral line (exclusive of dorsal base sheath scales) $3\frac{1}{2}$ ($3\frac{1}{2}$ to 4); from lateral line to anal fin origin 11; predorsal scales about 21 (about 20 to 24), extending to level of nostrils; teeth of jaws uniserial, relatively slender, with notched tips, about 50 in lower jaw and about 44 in upper jaw.

Body moderately deep, laterally compressed, the greatest depth 1.7 (1.8 to 1.9) in the standard length. Head profile rounded, the head length contained 3.2 (3.1 to 3.6) times in the standard length. The following proportions are expressed into the head length: snout 3.4 (3.5 to 3.9), eye diameter 3.7 (3.3 to 4.0), interorbital width 2.7 (2.8 to 3.5), least depth of caudal peduncle 1.7 (1.7 to 2.0), length of caudal peduncle 2.3 (2.0 to 2.3), of pectoral fin 0.9 (0.8 to 0.9), of pelvic fin 1.0 (0.9 to 1.1), of middle caudal rays 1.7 (1.5 to 1.8).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating $3\frac{1}{2}$ scale rows below middle of soft dorsal fin; preorbital, most of suborbital (which has a few scales posteriorly), snout, lips, chin, and isthmus naked; remainder of head and body scaled; scales finely ctenoid; preopercular scale rows 3 with additional row of scales on inferior limb; small sheath scales covering basal $\frac{1}{2}$ membranous portions of spinous dorsal, and nearly entire membranous portion of soft dorsal, anal, and caudal fins; margin of preorbital, suborbital, preopercle and bones of opercle series entire.

Origin of dorsal fin at level of fifth tubed scale of lateral line; spines of dorsal fin gradually increasing in length to about fourth spine, remaining spines about equal except last which is slightly longer. The following proportions are expressed into the head length: length of first dorsal spine 4.4 (3.7 to 5.1), of fourth dorsal spine 2.1 (1.9 to 2.4), of twelfth dorsal spine 1.9 (2.0 to 2.5), of last dorsal spine 1.7 (1.7 to 2.2), of longest soft dorsal ray 0.9 (0.7 to 1.1), of first anal spine 5.2 (4.2 to 5.4), of second anal spine 1.9 (1.7 to 2.2), of longest soft anal ray 1.2 (0.9 to 1.2).

Colour of holotype in alcohol: head and body mostly dark green (nearly blackish); pale streak in centre of each scale on lower half of body, giving appearance of eight narrow stripes running along length of body; scales of breast and abdomen whitish with brown margins, giving overall dusky appearance; scales of preopercle

and lower half of opercle with whitish mottling; dorsal, anal and caudal fins black; pelvic fins dusky; pectoral fins whitish with small black spot superiorly at base, invading upper half of axil.

All the paratypes except for the smallest are basically the same colour as the holotype. The colours of the smallest paratype (55 mm SL) are as follows: head and body silvery-white grading to brown above the lateral line; five narrow bars (about 1½ scales wide) on side of body; spinous dorsal fin and anterior portions of soft dorsal and anal fins brown; posterior portion of soft dorsal and anal fins tan; caudal fin with broad dark margins and tan central portion; pectoral fins pale with small dark spot superiorly at base.

Colour in life (from 35 mm transparency): head and body light blue-green grading to blue-white ventrally; eye noticeably blackish; five dark grey, narrow bars on sides extending from base of dorsal fin to lower portion of body, two posteriormost bars very faint; caudal fin, spinous dorsal and about distal three-fourths of soft dorsal and anal fins blackish; pelvic and pectoral fins pale; small blackish spot superiorly at base of pectoral fin extending on to upper half of axil.

Remarks: Abudefduf whitleyi belongs to a complex which contains several large, transverse barred species (except *sparoides*) including *abdominalis* (Hawaiian Islands), *bengalensis* (Indo-Australian Archipelago), *coelestinus* (Indo-W. Pacific), *notatus* (eastern Indian Ocean and Indonesia-Philippines), *affinis* (Indo-Australian Archipelago), *saxatilis* (circumtropical), *septemfasciatus* (Indo-W. Pacific), *sordidus* (Indo-W. Pacific), *sparoides* (western Indian Ocean) and *taurus* (southern Florida and Caribbean). These species characteristically have 13 dorsal spines, 3–4 scale rows above the lateral line (exclusive of the small dorsal sheath scales), and uniserial teeth which are relatively slender with notched tips. *A. whitleyi* appears to be closely allied to *saxatilis* and *notatus*. The latter species differs in colour, suborbital scalation and anal fin ray count. It is basically brownish in preservative with two to four pale bars on the sides. The suborbital is fully scaled and soft anal rays usually number 13 to 14. *A. saxatilis* differs on the basis of colour and a fully scaled suborbital, with some scalation on the preorbital as well. The upper back of *saxatilis* is generally bright yellow (at least in Australian specimens) and the dark transverse bars are nearly twice the width of those found on *whitleyi*.

Young individuals (less than about 70 mm SL) bear a resemblance to *A. coelestinus* Cuvier and Valenciennes because of the dark margins on the caudal fin. However, the middle portion of the fin darkens with growth and eventually becomes entirely blackish. The dark margins of *coelestinus* persist in adults and are diagnostic for the species. The name *sexfasciatus* (Lacépède) has been used in place of *coelestinus* in the recent literature, but we agree with De Beaufort (1940) in placing *sexfasciatus* in the synonymy of *A. saxatilis*.

A. whitleyi is very common on the Great Barrier Reef. It generally lives in relatively shallow water (to depths of about five metres) along the perifery of the outer reef edge. Feeding aggregations composed of a hundred or more individuals are frequently observed swimming high above the substratum. They appear to be feeding on zooplankton, but the stomachs of several specimens which were examined contained nearly 100% algae. Perhaps they selectively feed on bits of algae which are washed off the reef flat by waves and currents.

The smallest ripe female examined was 103 mm SL.

This species is named after Gilbert P. Whitley in honour of his many contributions to Australian ichthyology.

Abudefduf flavipinnis n.sp.

(Plate 2; Table 4)

Holotype: AMS I.16481–001, 57 mm SL, Pixie Reef, Great Barrier Reef, off Cairns, Queensland, Australia, 20 m, quinaldine and dipnets, G. R. Allen, 2 July 1972.

Paratypes: AMS I.16482–001, 3 (15–58), Pixie Reef, Great Barrier Reef, 20–23 m, multi-prong spear, G. R. Allen & W. A. Starck II, 1–2 July 1972; AMS IB.4788, 1 (36), Swains Reef, Great Barrier Reef, Queensland, Australia, A. J. Meagher (no date); AMS I.15622–008, 1 (18), One Tree Island, Capricorn Group, Great Barrier Reef, 13 m, explosives, F. H. Talbot & party, 28 November 1966; AMS I.15625–009, 13 (39–56), same data as AMS I.15622–008 except 33 m, 8 December 1966; AMS I.15635–002, 1 (40), same data as AMS I.15622–008 except 12 m, 3 October 1967; AMS I.15637–011, 1 (44), same data as AMS I.15622–008 except 23 m, 5 October 1967; AMS I.15682–001, 6 (36–49), same data as AMS I.15622–008 except 33 m, 27 November 1969; AMS I.15684–005, 6 (39–50), same data as AMS I.15622–008 except 32 m, 1 December 1969; AMS I.16636–001, 1 (57), same data as AMS I.15622–008 except 22 m, rotenone 3 December 1969; BPBM 13228, 4 (37–51), Samarai Island, New Guinea, near public wharf, 9.5 m, multi-prong spear, G. R. Allen, 16 June 1972; BMNH.1972.8.14.6–7, 2 (41), same data as BPBM 13228; MNHN 1972–88, 2 (43–51), same data as BPBM 13228.

Diagnosis: A species of *Abudefduf* with the following combination of characters: dorsal rays usually XIII, 14½; horizontal scale rows between middle of lateral line and dorsal fin base 1 to 1½; predorsal scales extending to front of orbits, not reaching nostrils; inferior limb of preopercle with several small scales; teeth biserial; contour of dorsal fin outline relatively uniform, membranes between dorsal spines, not deeply incised; colour blue with forehead, ventral body region and fins yellow.

Description: The proportional measurements of the holotype and several paratypes are expressed as percentage of the SL in Table 4.

Dorsal rays XIII,14½ (XIII,11 to 14½); anal rays II,14 (II,13 to 14); pectoral rays 17 (17 to 18); pelvic rays I,5; branched caudal rays 13; gill rakers on the first arch 21 (19 to 23); tubed lateral line scales 17 on left side, 16 on right side (15 to 18); vertical scale rows from upper edge of gill opening to base of caudal fin 28; horizontal scale rows from base of dorsal fin to middle of lateral line (exclusive of dorsal base sheath scales) 1½ (1 to 1½); from lateral line to anal fin origin 9 (8 to 9); predorsal scales about 16 (13 to 15), extending to front of orbits; teeth of jaws biserial (at least anteriorly), compressed with bluntly rounded tips, about 35 to 40 in the front row of each jaw, teeth of the outer row about four times larger than inner row teeth.

Body relatively elongate, laterally compressed, the greatest depth 2.5 (2.2 to 2.6) in the standard length. Head profile conical, the head length contained 3.4 (3.0 to 3.5) times in the standard length. The following proportions are expressed into the head length: snout 4.9 (4.3 to 4.9), eye diameter 2.8 (2.4 to 3.1); inter-orbital width 3.9 (3.9 to 4.3), least depth of caudal peduncle 1.9 (1.9 to 2.4), length of caudal peduncle 3.0 (2.8 to 3.4), of pectoral fin 1.0 (0.9 to 1.1), of pelvic fin 1.1 (1.1 to 1.3), of middle caudal rays 1.2 (1.2 to 1.4).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating 1½ (1 to 1½) scale rows below base of first (first to third) soft dorsal ray; preorbital, suborbital, snout, lips,

chin and isthmus naked; remainder of head and body scaled; scales finely ctenoid except cheek scales which are cycloid; preopercular scale rows 2, additional row of smaller scales covering upper half of inferior limb; small sheath scales covering about basal 1/2 to 3/4 of membranous portions of dorsal, anal, and caudal fins; margin of preorbital, suborbital, and bones of opercle series entire.

Origin of dorsal fin at level of second tubed scale of lateral line; spines of dorsal fin gradually increasing in length to about sixth or seventh spine, remaining spines about equal or slightly longer than seventh spine. The following proportions are expressed into the head length: length of first dorsal spine 4.3 (4.6 to 5.2), of seventh dorsal spine 1.9 (1.9 to 2.3), of last dorsal spine 1.8 (1.7 to 2.2), of longest soft dorsal ray 1.3 (1.2 to 1.9), of first anal spine 4.3 (4.4 to 5.0), of second anal spine 1.9 (1.8 to 2.1), of longest soft anal ray 1.3 (1.3 to 1.7).

Colour of holotype in alcohol: most of head and body brownish-blue; ventral portion of head, body, and entire caudal peduncle pale yellow, slightly dusky on head; dorsal fin and portion of back immediately adjacent pale yellow with dusky yellow extension covering predorsal region to rear of orbits; remainder of fins pale yellow; thin black margin on dorsal and anal fins; small black spot superiorly at pectoral base invading axil.

Colour in life: most of head and body bright blue; forehead yellow with pattern of fine blue lines; snout, interorbital, dorsal fin and portion of back immediately adjacent, caudal peduncle, ventral portion of head and body, and all fins brilliant yellow; thin black margin on dorsal and anal fins; small black spot superiorly at pectoral base invading axil.

Remarks: A. flavipinnis is a member of the subgenus *Glyphidodontops* (*Chrysiptera* of some authors). The group is characterized by a relatively elongate body shape and biserial dentition. *A. flavipinnis* is closely related to *A. cyaneus* (Quoy and Gaimard), which is generally bright blue with one or more of the vertical fins yellow to orange (except juveniles and female specimens from some localities which have translucent fins). The latter usually has 10 to 12 soft dorsal rays and the membranes of the spinous dorsal are deeply incised, at least anteriorly. Furthermore, it does not possess a yellow snout, interorbital, and forehead and, unlike *flavipinnis*, occurs in shallow water (usually less than five metres).

This species was observed at depths ranging from 9.5 metres (Samarai Island) to 37 metres (Osprey Reef, Coral Sea). It is generally solitary in habit or occurs in pairs, sometimes forming colonies of up to a dozen individuals or more. It is found among rubble or around dead coral outcrops which are frequently situated in sandy areas.

Named *flavipinnis* in reference to the striking yellow fins.

Pomacentrus australis n.sp.

(Plate 3; Table 5)

Holotype: AMS I.16592–001, 59 mm SL, outer reef off east side of One Tree Island Reef (23° 30′ S, 152° 05′ E), Capricorn Group, Great Barrier Reef, 16 m, quinaldine and dipnet, G. R. Allen, 4 October 1972.

Paratypes: AMS I.16524–002, 1 (53), Swansea, Lake Macquarie, New South Wales, J. Lewis, June 1972; AMS I.16592–002, 6 (30–53), collected with the holotype; AMS I.16593–001, 1 (35), One Tree Island, in large pool at low tide on reef flat,

1 m, rotenone, G. R. Allen, F. H. Talbot, D. F. Hoese, D. J. G. Griffin & B. C. Russell, 6 October, 1972; AMS I.15622–007, 1 (55), One Tree Island, 13 m, explosives, F. H. Talbot & party, 28 November 1966; AMS I.15625–007, 7 (44–55), same data as AMS I.15622–007 except 33 m, 8 December 1966; AMS I.15637–010, 10 (39–57), same data as AMS I.15622–007 except 23 m, 5 October 1967; AMS I.15679–005, 2 (52–60), same data as AMS I.15622–007 except 5 m, 21 November 1969; AMS IA.6758, 1 (59), Lindeman Island, Queensland, G. P. Whitley, 9 August 1935; BPBM 13607, 3 (47–54), outer reef off west side of One Tree Island Reef, 30 m, quinaldine & dipnet, G. R. Allen on 2 October 1972.

Diagnosis: A species of *Pomacentrus* with the following combination of characters: greatest body depth 2.2 to 2.6 in SL; dorsal spines 14; pectoral rays usually 18; preorbital and suborbital naked with serrate edges, teeth of jaws biserial, those of outer row somewhat spatulate with rounded tips; head and body entirely blue (brown in preservative) or blue dorsally and whitish on ventral half.

Description: The proportional measurements of the holotype and several paratypes are expressed as percentage of the SL in Table 5.

Dorsal rays XIV,13½ (XIV–XV,12 to 14½); anal rays II,14½ (II,14½ to 15½); pectoral rays 18 (17 to 19); pelvic rays I,5; branched caudal rays 13; gill rakers on the first arch 20 (19 to 21); tubed lateral line scales 17 on left side, 18 on right side (17 to 19); vertical scale rows from upper edge of gill opening to base of caudal fin 28 (27 to 28); horizontal scale rows from base of dorsal fin to middle of lateral line (exclusive of dorsal base sheath scales) 1½; from lateral line to anal fin origin 9; predorsal scales about 17 (17 to 20), extending to about level of nostrils; teeth of jaws biserial (at least anteriorly), those of outer row somewhat spatulate with rounded tips, about 32 in lower jaw and 42 in upper jaw; teeth of inner row slender, about ½ width of outer row teeth.

Body elongate, laterally compressed, the greatest depth 2.5 (2.2 to 2.6) in the standard length. Head profile conical, the head length contained 3.4 (3.2 to 3.5) times in the standard length. The following proportions are expressed into the head length: snout 3.6 (3.8 to 4.4), eye diameter 3.1 (2.8 to 3.3); interorbital width 3.6 (2.8 to 3.3), least depth of caudal peduncle 2.2 (1.9 to 2.3), length of caudal peduncle 2.9 (2.7 to 3.3), of pectoral fin 1.1 (1.0 to 1.2), of pelvic fin 1.1 (1.0 to 1.1), of middle caudal rays 1.2 (1.1 to 1.4).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating 1½ scale rows below base of first soft dorsal ray; preorbital, suborbital, snout, lips, chin, and isthmus naked; remainder of head and body scaled; scales finely ctenoid; preopercular scale rows 3; inferior and posterior limb naked; small sheath scales covering about basal 1/2 to 3/4 of membranous portions of dorsal, anal, and caudal fins; preopercle armed with single spinule; edge of suborbital and preopercle denticulate; edge of bones of opercle series entire except one or two flattened projections on upper portion of opercle.

Origin of dorsal fin at level of third tubed scale of lateral line; spines of dorsal fin gradually increasing in length to last spine. The following proportions are expressed into the head length: length of first dorsal spine 4.5 (3.8 to 5.2): of seventh dorsal spine 2.2 (2.1 to 2.5), of last dorsal spine 2.0 (2.1 to 2.5); of longest soft dorsal ray 1.5 (1.4 to 1.7); of first anal spine 5.0 (4.0 to 5.4), of second anal spine 2.2 (2.0 to 2.6), of longest soft anal ray 1.5 (1.5 to 1.6).

Colour of holotype in alcohol: head and body generally dark blue, paler ventrally and on caudal peduncle; three pale lines on anterior portion of head, the first from front of eye to lip (just below nostril), the second extending along suborbital and preorbital onto lip, and the third extending along uppermost row of scales on preopercle; small black spot on suprascapula, near origin of lateral line; pectoral base dusky; dorsal and anal fins blue-grey with pale submarginal band; pelvic and pectoral fins whitish or slightly grey; caudal fin whitish, faintly dusky along posterior margin.

Many of the recently collected paratypes are entirely dark blue except for pale pectoral, pelvic, and caudal fins. A few are blue dorsally and abruptly whitish on the ventral half of the body. After several years of preservation in isopropyl alcohol the bluish colour tends to turn brown and the pale lines of the snout and preopercle disappear.

Colour in life: two basic colour patterns were observed at the Capricorn Group. Individuals were either mostly dark blue (except for the pale fins mentioned above) or sky-blue above and whitish on the ventral half of the body, with the demarkation between the light and dark areas angling upwards posteriorly. The blue of the dark form is somewhat iridescent and the scales of the body have dusky margins which results in a crosshatch pattern. Both forms have a dark grey forehead and a pattern of pale blue submarginal stripes on the anal fin.

Remarks: The combination of characters listed under the diagnosis are sufficient for distinguishing this species. At first glance it might be mistaken for *P. pavo* (Bloch). Both species are blue, relatively elongate, and possess a dark suprascapular spot. However, *P. pavo* differs in having 13 dorsal spines and 13 to 13½ soft anal rays. It is pale iridescent blue with a pattern of blue iridescent lines on the head and an oval iridescent blue spot on each body scale. Both species were observed in the lagoon at One Tree Island in depths as shallow as 1½ metres. The typical lagoon habitat consisted of open sandy areas with occasional coral outcrops, which provide refuge for several pomacentrid species. *P. australis*, unlike *P. pavo*, was also present on the outer reef slope, generally in rubble areas, ranging in depth from 12 to 35 metres. It occurs solitarily or in groups composed of several individuals. Feeding takes place a short distance above the bottom. The stomach contents of several paratypes we examined were in an advanced state of digestion, but appeared to consist mainly of zooplankton.

This pomacentrid has not been collected outside of Australian waters and in reference to its southern distribution is named *australis*.

Pomacentrus pseudochrysopoecilus n.sp.

(Plates 4 and 5A; Table 6)

Holotype: BPBM 13608, 62 mm SL, off north side of Naura Islet (9° 36′ S, 150° 27′ E), Fergusson Island, D'Entrecasteaux Group, 2 m, quinaldine, G. R. Allen, 30 May 1972.

Paratypes: AMS I.15633-006, 7 (75–101), One Tree Island, Capricorn Group, Great Barrier Reef, 2 m, explosives, F. H. Talbot & party, 30 September, 1967; AMS I.16479-001, 3 (48–78), same data as holotype; QM I.6009, 1 (125), Hopkinson Reef, off Townsville, Australia, G. Coates, 13 September, 1937; USNM 207936, 2 (65–69), same data as holotype except collected with rotenone and multi-prong spear.

Diagnosis: A species of *Pomacentrus* with the following combination of characters: dorsal spines 13; preorbital and suborbital naked except 1 or 2 small scales on posterior portion of suborbital; notch lacking between preorbital and suborbital; lower margin of preorbital and suborbital denticulate; snout scaled to level of nostrils; teeth biserial; ground colour of head and body brown, usually with one or two pale saddles (sometimes absent in preservative) dorsally at middle of body which extend at least $1\frac{1}{2}$ scale rows below lateral line; large adults frequently without pale saddles; juveniles with two, broad, white bars on sides (extending on to dorsal fin) with large ocellus between bars on dorsal fin.

Description: The proportional measurements of the holotype and several paratypes are expressed as percentage of the SL in Table 6.

Dorsal rays XIII,14 (XIII,13 to $14\frac{1}{2}$); anal rays II,$13\frac{1}{2}$ (II,13 to $13\frac{1}{2}$); pectoral rays 17; pelvic rays I,5; branched caudal rays 13; gill rakers on the first gill arch 21 (20 to 22); tubed lateral line scales 16 on right side, 18 on left side (16 to 18); vertical scale rows from upper edge of gill opening to base of caudal fin 28; horizontal scale rows from base of dorsal fin (at soft dorsal junction) to middle of lateral line (exclusive of dorsal base sheath scales) $1\frac{1}{2}$; from lateral line to anal fin origin 9; predorsal scales about 18 (about 19 to 23), extending well forward of anterior edge of orbits, about to level of nostrils; teeth biserial, long and slender with rounded tips, those of the outer row close set, about twice as large as those of the inner row.

Body moderately deep and laterally compressed, the greatest depth 2.0 (2.0 to 2.3) in the standard length. Head profile conical; the head length contained 3.3 (3.3 to 3.5) times in the standard length. The following proportions are expressed into the head length: snout 3.9 (3.4 to 3.8), eye diameter 3.0 (2.6 to 3.3), interorbital width 4.1 (3.6 to 3.9), least depth of caudal peduncle 1.9 (1.7 to 1.9), length of caudal peduncle 2.8 (2.5 to 3.0), of pectoral fin 1.1 (1.1 to 1.2), of pelvic fin 1.0 (1.0 to 1.1), of middle caudal rays 1.1 (1.1 to 1.2).

Single nasal opening on each side of snout; mouth oblique, terminally located; lateral line gently arched beneath dorsal fin, terminating $1\frac{1}{2}$ scale rows below base of first to third soft dorsal rays; preorbital, most of suborbital, tip of snout, lips, chin and isthmus naked, remainder of head and body scaled; scales finely ctenoid, preopercular scale rows 3, additional row of smaller scales on inferior limb; small sheath scales covering basal $\frac{1}{2}$ of spinous dorsal, basal 2/3 of soft dorsal and anal fins, and basal 3/4 of caudal fin; lower margin of preorbital and suborbital denticulate; posterior margin of preopercle denticulate; posterior margin of opercle entire except for two blunt projections on upper portion.

Origin of dorsal fin at level of third tubed scale of lateral line; spines of dorsal fin gradually increasing in length to last spine. The following proportions are expressed into the head length: length of first dorsal spine 2.8 (3.3 to 4.6), of last (13th) dorsal spine 1.7 (1.6 to 1.7), of longest soft dorsal ray 1.2 (1.1 to 1.3), of first anal spine 5.6 (3.7 to 4.5), of second anal spine 1.9 (1.8 to 2.1), of longest soft anal ray 1.3 (1.2 to 1.3).

Colour of holotype in alcohol: ground colour of head and body brown, darker anterodorsally; numerous pale spots on scales of preopercle and opercle; a single whitish bar or saddle dorsally at middle of body, originating at the base of dorsal spines IX–XII and terminating $1\frac{1}{2}$ scales below lateral line; small black spot superiorly at pectoral base; anus black; dorsal, anal, pelvic, and caudal fins dusky; pectoral fin pale.

58270-B

The largest paratype is completely dark brown, except for the pale pectoral fins and narrow blue streaks on each scale of the body. The 65 mm and 75 mm paratypes faintly retain the posterior-most bar as described below under colour in life of the holotype. The two saddles or bars of these individuals, however, extend halfway down the sides, gradually tapering to a point. The pale saddles are missing on the paratypes from One Tree Island. These specimens are entirely brown except for pale pectoral fins. A black suprascapular spot is faded and scarcely visible on the holotype, but vivid in the paratypes. The smallest paratype (fig. 5A) retains the juvenile colour pattern characterized by two broad white bars with a large yellow-ringed black ocellus between the two bars on the dorsal fin.

Colour of holotype in life: ground colour of head and body brown, dark brown anterodorsally; scales of preopercle and opercle with numerous blue dots; two whitish bars or saddles on dorsal portion of body, the first originating from base of dorsal spines IX–XII and terminating $1\frac{1}{2}$ scales below lateral line, the second (which disappears rapidly after death) extending from base of soft dorsal rays 4–9 to same level as anterior bar; black spot about $\frac{1}{2}$ pupil diameter at lateral line origin; small black spot superiorly at pectoral base; anus black; thin blue streak at centre of each scale of body, but not detracting from overall brownish appearance; dorsal fin dusky or brownish basally, bluish distally with thin black margin and two submarginal orange bands; anal fin dusky brown basally, distal portion orange with three oblique submarginal bands of blue; pelvics cinnamon brown; pectorals pale yellow; caudal fin brown basally, bluish distally with orange margins.

Most of the individuals sighted at Fergusson Island were generally brown with two white saddles. However, many adults were observed on the Great Barrier Reef which were entirely dark brown with a single saddle. These individuals can easily be mistaken for *P. chrysopoecilus* (see Remarks section below). At Egum Atoll, Solomon Sea, several large (approximately 180 mm TL) individuals were observed which were entirely dark brown without any characteristic markings. Apparently the saddles disappear gradually with growth.

Remarks: *P. pseudochrysopoecilus* is closely related to *P. chrysopoecilus* Schlegel and Muller and *P. fasciatus* Cuvier and Valenciennes. Its colour pattern (especially in preservative) is very similar to that of *P. chrysopoecilus* and it has probably been included with this species in the past. Fowler and Bean's (1928) plate 11 of a colour variant of *P. pristiger* is probably *P. pseudochrysopoecilus* on the basis of the midbody bar configuration. It is possible that plate 12 of the same work is also a figure of this species, rather than another variant of *P. pristiger*. The midbody bar in both these figures extends below the lateral line. *P. chrysopoecilus* is not a junior synonym of *P. pristiger* as stated by Fowler and Bean. The latter species was described from Mauritius and has 12 dorsal spines. It is possibly synonymous with *P. nigricans*, a widely distributed species of the Indo-Pacific. The live colour pattern (Table 7) and total number of gill rakers on the first gill arch (23–24 in 13 specimens of *chrysopoecilus*) constitute the principal differences between *chrysopoecilus* and *pseudochrysopoecilus*. The juvenile colour patterns of like-sized individuals of these species are contrasted in Figure 5. Specimens of *chrysopoecilus* under 25 mm SL, which were observed at Fergusson Island, were uniformly dark, except for pale pelvic, pectoral, and caudal fins, pale abdominal region, a whitish bar below the middle of the spinous dorsal extending to the level of the pectoral fins, a pale band on the forehead, and a large ocellus near the soft dorsal junction. *P. pseudochrysopoecilus* individuals under 25 mm SL were essentially marked as shown in Figure 5. Furthermore, the two species were sympatric, but clearly separated ecologically at the D'Entrecasteaux Group. At Naura Islet in the vicinity of the type locality, there is an extensive inshore reef, about 300 metres wide, which plunges abruptly

to deeper water on the outer edge. The average depth of the inshore reef is 1 to 1.5 metres. *P. pseudochrysopoecilus* was confined to a narrow belt, just inside the algal ridge, about 50 metres from the outer edge. The bottom consisted primarily of live coral thickets interspersed with open areas of sand and dead coral. The water in this area was generally clear with visibility in excess of 25 metres. *P. chrysopoecilus* was encountered in a belt, about 50 metres wide, directly adjacent to the shoreline Naura Islet. The area was characterized by heavy silting and murky water. The uniformly flat bottom was composed of consolidated coral rock, interrupted occasionally with patches of rocks and turtle grass. Thus, the two habitat zones were separated by a horizontal distance of approximately 200 metres. *P. chrysopoecilus* has been recorded from Indonesia, the Philippines, New Guinea and the Palau Islands.

P. fasciatus differs primarily in colour pattern, although it is reported to have predorsal scales which extend only to the middle of the interorbital, as opposed to the fully scaled interorbital of *P. pseudochrysopoecilus*. It is basically a brown fish with four yellow bars (located behind the eye, below the anterior and posterior portion of the spinous dorsal, and at the upper caudal peduncle). This species was not observed along the southeast coast of New Guinea (Madang to Samarai, including the D'Entrecasteaux Group), but has been reported from Queensland (one specimen), northern Australia, Indonesia, and the Philippines.

Named *pseudochrysopoecilus* because of the close resemblance to *chrysopoecilus*.

ACKNOWLEDGMENTS

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Table 1

Dorsal and Anal Fin Ray Counts for New Pomacentrids from New Guinea, Solomon Sea, and The Great Barrier Reef

Species	Dorsal Rays												Anal Rays									
	XIII	XIV	11	11½	12	12½	13	13½	14	14½	15	15½	II	12	12½	13	13½	14	14½	15	15½
Abudefduf whitleyi	19	1	..	..	..	..	20	..	..	..	..	..	20	20	..	..	..	..	..	..	..
A. flavipinnis	21	..	1	..	..	..	1	..	5	14	..	..	21	..	..	4	14	3	..	..	..
Pomacentrus australis	..	32	..	..	1	1	2	22	2	4	..	..	32	..	..	..	..	..	25	4	3
P. pseudochrysopoecilus	13	..	..	..	..	..	1	..	2	10	..	..	13	..	..	2	10	1	..	..	..

Table 2

Pectoral Ray, Gill Raker, and Tubed Lateral Line Scale Counts for New Pomacentrids from New Guinea, Solomon Sea, Coral Sea, and The Great Barrier Reef

Species	Pectoral Rays					Gill Rakers							Tubed Lateral Line Scales							
	16	17	18	19	20	18	19	20	21	22	23	24	15	16	17	18	19	20	21	22
Abudefduf whitleyi	..	..	..	6	14	..	..	..	..	2	10	8	..	..	..	..	..	18	2	2
A. flavipinnis	..	4	16	1	..	..	1	4	9	6	1	..	3	10	4	1	..	..	..	..
Pomacentrus australis	..	9	19	4	..	..	4	8	10	..	..	..	..	1	8	14	6	..	..	..
P. pseudochrysopoecilus	1	12	..	..	..	..	..	2	7	4	..	..	..	3	5	4	..	..	..	..

Table 3

Morphometric Proportions (in % of SL) of Twenty Specimens of *Abudefduf whitleyi* from The Great Barrier Reef

Morphometric measurement	Range (% SL)	Mean (% SL)
Standard length (SL)	95–132	..
Body depth	51.9–58.4	54.6
Head length	28.1–31.8	29.9
Snout length	7.5–9.0	8.2
Eye diameter	7.8–8.6	8.3
Interorbital width	8.8–11.3	9.7
Least depth of caudal peduncle	15.5–17.9	16.5
Length of caudal peduncle	12.9–14.5	13.6
Snout to origin of dorsal fin	38.9–43.7	41.8
Snout to origin of anal fin	70.0–75.8	72.1
Snout to origin of pelvic fin	40.9–45.8	42.8
Length of dorsal fin base	57.3–61.6	58.9
Length of anal fin base	20.6–23.2	22.0
Length of pectoral fin	33.1–36.5	34.5
Length of pelvic fin	28.4–33.5	30.6
Length of pelvic spine	14.8–17.0	15.8
Length of 1st dorsal spine	6.2–8.0	7.0
Length of 4th dorsal spine	12.4–14.6	13.8
Length of 12th dorsal spine	12.6–16.0	14.1
Length of last dorsal spine	14.7–18.5	16.3
Length of longest soft dorsal ray	29.8–40.6	33.1
Length of 1st anal spine	5.7–7.2	6.5
Length of 2nd anal spine	14.0–16.6	15.5
Length of longest anal ray	25.6–33.4	29.6
Length of middle caudal rays	16.6–20.1	18.5

Table 4

Morphometric Proportions (in % of SL) of Ten Specimens of *Abudefduf flavipinnis* from Samarai, New Guinea and The Great Barrier Reef

Morphometric measurement	Range (% SL)	Mean (% SL)
Standard length (SL)	37–57	..
Body depth	39.0–46.5	42.2
Head length	29.0–32.4	30.8
Snout length	6.0–7.3	6.7
Eye diameter	9.9–13.4	12.1
Interorbital width	6.9–8.1	6.9
Least depth of caudal peduncle	13.4–15.3	14.0
Length of caudal peduncle	9.1–11.1	9.9
Snout to origin of dorsal fin	32.3–37.1	34.1
Snout to origin of anal fin	63.0–73.6	67.4
Snout to origin of pelvic fin	37.9–48.4	41.8
Length of dorsal fin base	57.6–69.3	63.1
Length of anal fin base	23.1–27.5	25.3
Length of pectoral fin	28.8–32.7	30.5
Length of pelvic fin	25.0–27.7	26.6
Length of pelvic spine	15.0–17.2	16.4
Length of 1st dorsal spine	5.8–7.3	5.8
Length of 5th dorsal spine	13.6–15.8	14.9
Length of 14th dorsal spine	14.8–18.4	16.1
Length of longest soft dorsal ray	19.4–24.8	21.2
Length of 1st anal spine	6.3–7.1	6.7
Length of 2nd anal spine	15.0–17.1	16.2
Length of longest anal ray	18.5–22.9	20.9
Length of middle caudal rays	21.8–25.5	24.1

Table 5

Morphometric Proportions (in % of SL) of Fifteen Specimens of *Pomacentrus australis* from The Great Barrier Reef

Morphometric measurement	Range (% SL)	Mean (% SL)
Standard length (SL)	48–60	..
Body depth	38.0–44.5	41.3
Head length	28.2–30.7	29.9
Snout length	6.9–8.1	7.3
Eye diameter	9.3–11.1	9.9
Interorbital width	6.2–8.1	7.2
Least depth of caudal peduncle	13.4–15.7	14.2
Length of caudal peduncle	9.6–10.9	10.4
Snout to origin of dorsal fin	33.2–36.7	35.0
Snout to origin of anal fin	63.8–82.1	67.7
Snout to origin of pelvic fin	37.4–43.2	39.5
Length of dorsal fin base	59.6–64.5	62.5
Length of anal fin base	25.9–29.5	27.1
Length of pectoral fin	25.8–29.1	27.4
Length of pelvic fin	27.1–30.4	28.8
Length of pelvic spine	14.7–17.2	15.9
Length of 1st dorsal spine	5.6–7.9	6.7
Length of 7th dorsal spine	12.2–14.4	13.4
Length of last dorsal spine	13.7–17.4	15.2
Length of longest soft dorsal ray	18.3–21.4	20.5
Length of 1st anal spine	5.3–7.5	6.2
Length of 2nd anal spine	11.1–15.5	13.2
Length of longest anal ray	16.2–20.8	19.2
Length of middle caudal rays	21.8–25.0	23.3

Table 6

Morphometric Proportions (in % of SL) of Ten Specimens of *Pomacentrus pseudochrysopoecilus* from Fergusson Island, D'Entrecasteaux Group and One Tree Island, Great Barrier Reef

Morphometric measurement	Range (% SL)	Mean (% SL)
Standard length (SL)	62–101	..
Body depth	44.9–48.8	46.1
Head length	28.4–31.0	29.8
Snout length	7.8–8.3	8.0
Eye diameter	9.1–10.5	9.8
Interorbital width	7.7–8.2	7.9
Least depth of caudal peduncle	16.2–17.1	16.6
Length of caudal peduncle	10.4–12.0	11.1
Snout to origin of dorsal fin	35.6–37.1	36.2
Snout to origin of anal fin	65.9–69.3	68.0
Snout to origin of pelvic fin	37.2–41.7	39.3
Length of dorsal fin base	60.4–62.9	61.8
Length of anal fin base	24.0–25.4	24.4
Length of pectoral fin	25.0–27.4	26.6
Length of pelvic fin	28.1–30.2	28.9
Length of pelvic spine	16.7–18.6	17.3
Length of 1st dorsal spine	6.5–7.7	6.8
Length of last dorsal spine	17.7–18.4	18.2
Length of longest soft dorsal ray	24.2–26.4	25.0
Length of 1st anal spine	5.5–7.5	6.8
Length of 2nd anal spine	14.4–16.0	15.1
Length of longest anal ray	22.6–24.6	23.7
Length of middle caudal rays	25.7–28.2	26.6

Table 7

Principal Colour Pattern Differences between Live Adult Specimens of *Pomacentrus pseudochrysopoecilus* and *P. chrysopoecilus* from Fergusson Island

P. pseudochrysopoecilus	*P. chrysopoecilus*
Pale saddle usually below dorsal spines IX–XII and extending at least $1\frac{1}{2}$ scales below lateral line.	Pale saddle usually below dorsal spines VI–IX and terminating at lateral line.
Pale saddle frequently present below soft dorsal fin.	Saddle below soft dorsal fin absent.
Forehead dark brown.	Whitish bar across forehead.
Distal half of dorsal fin with alternating orange and blue submarginal bands.	Distal half of dorsal fin more or less uniform.
Pelvic fins light brown.	Pelvic fins blackish or dark grey.
Caudal fin dusky to brown.	Caudal fin pale.

PLATES

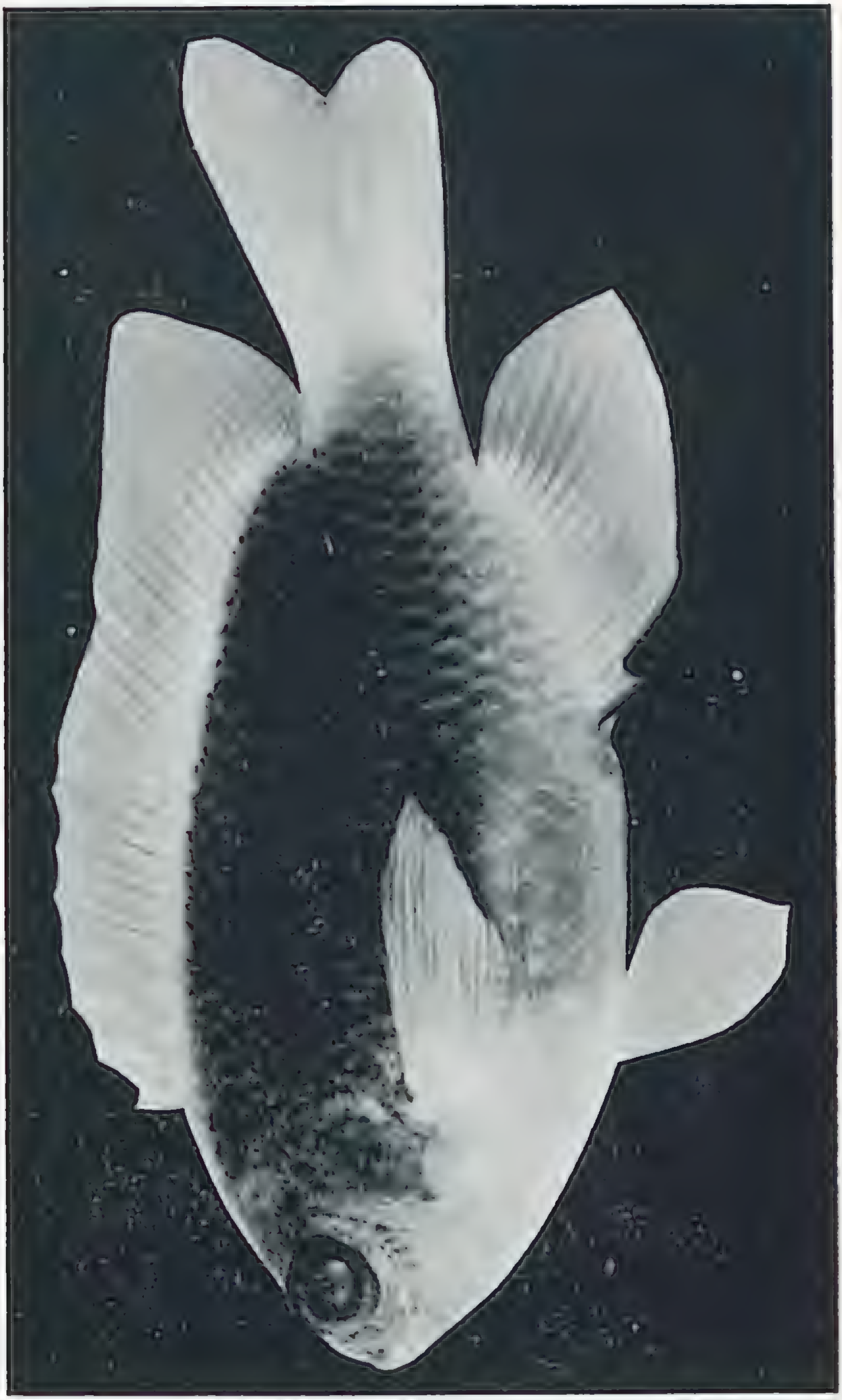
Plate 1. *Abudefduf whitleyi*, holotype, standard length 132 mm (photo by Charles Turner).

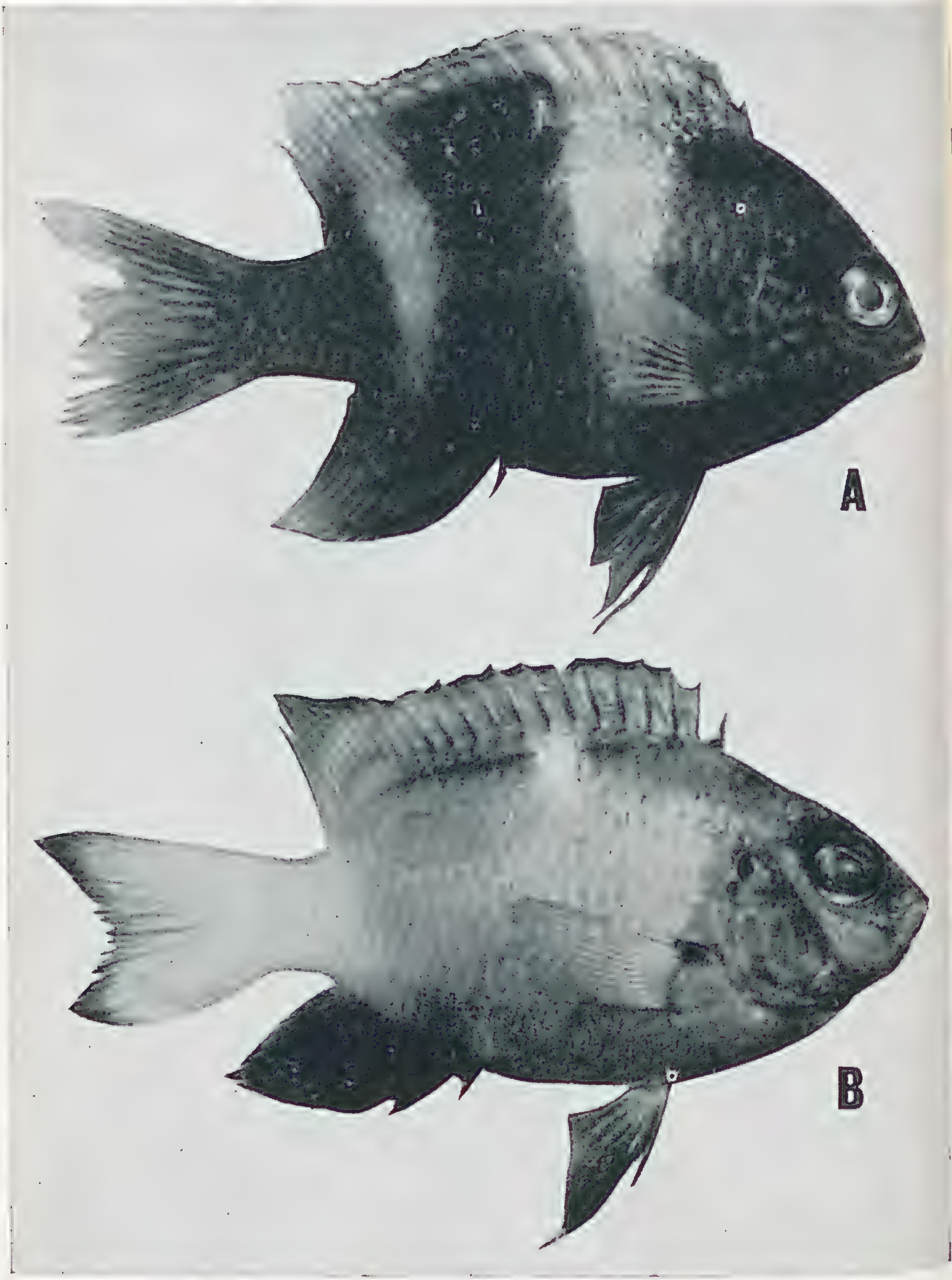
Plate 2. *Abudefduf flavipinnis*, holotype, standard length 57 mm.

Plate 3. *Pomacentrus australis*, holotype, standard length 59 mm (photo by Charles Turner).

Plate 4. *Pomacentrus pseudochrysopoecilus*, holotype, standard length 62 mm.

Plate 5. A. *Pomacentrus pseudochrysopoecilus*, paratype, standard length 48 mm; B. *P. chrysopoecilus*, standard length 50 mm. Both specimens from Fergusson Island, D'Entrecasteaux Group.

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NOTES ON AUSTRALIAN METEORITES

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Plates 6 and 7. Figures 1 and 2. Manuscript received 3rd June, 1973.

ABSTRACT

A review of Australian meteorites, eliminating paired falls, gives a total of 184, comprising 67 irons, 9 stony-irons, and 108 stones (6 anchondrites and 102 chondrites); 10 of these were observed falls. Olivine and pyroxene compositions have been determined by microprobe analysis for most of the chondrites, and they have been examined microscopically and classified according to the Van Schmus-Wood classification. Additional data on mineral compositions are given for the enstatite achondrite Mt Egerton and the ureilites North Haig and Dingo Pup Donga; a bulk analysis of a small sample of the eucrite Emmaville has been made. Ringwoodite and majorite are recorded from the Coolamon meteorite, the third occurrence of these meteorite minerals. A list of Australian irons and stony-irons, giving Ni and Ge contents, structural type, and Ge-Ga class has been compiled, and the Ni-Ge data presented in a diagram.

INTRODUCTION

Research on Australian meteorites may perhaps be dated from 1861, the year in which Haidinger published the first account of the Cranbourne irons. At that time two were known, one (the largest of the ten or more now known) weighing 3.5 tons and the other 1.5 tons, both having been found in 1854. The 3.5 ton mass was transported to London and displayed at an exhibition in 1862, being the largest meteorite known at that time, and is now in the British Museum collection. The literature on Cranbourne is very extensive, and has been summarized by Edwards and Baker (1944).

The Barratta meteorite is possibly an even earlier discovery. First described by Liversidge in 1872, it had been obtained by the Government Astronomer, H. C. Russell, when he visited Barratta in April 1871. The actual discovery of the meteorite, according to Russell, was the subject of some disagreement. A stockman said that he saw a brilliant fireball in May, 10 or 12 years earlier (i.e., about 1860), and that the following day some fencers who were camped about four miles northwest of the homestead reported having seen a stone fall near their camp. The stockman went to the place a few days later and saw the meteorite about half-buried in the ground. However, a Mr F. Gwynne, living in the neighbourhood, claimed that he found the meteorite when riding over the plain about the year 1845. In spite of additional inquiries, Russell was unable to resolve the matter. Possibly isotopic analyses could provide an answer, by giving an approximate terrestrial age.

Another early meteorite is the Narraburra iron, found near Temora in 1855, but not reported in the literature till many years later (Russell, 1890). Actually, throughout the nineteenth century meteorites were evidently found but did not come to the attention of the scientific community because of the sparse population and poor communications. A particularly interesting instance is the first fall recorded, the Tenham shower in western Queensland in 1879. This was a spectacular event, seen by the local station owners, and hundreds of stones were collected. However, it was first described by Prior in 1916 under a false locality (Warbreccan), and the details of the fall were assembled and published by Spencer in 1937, almost sixty years after the event.

Several enumerations of Australian meteorites have been published, the first of consequence being that of Cooksey (1897), and these are summarized in Table 1. It is intriguing, as mentioned above, that so few meteorites were recorded by 1897 after over a century of exploration and occupation. The intensive prospecting for gold and other mineral deposits might have been expected to yield some meteorites—however, prospectors probably avoided those areas most favorable to meteorite finds, i.e. the flat sandy regions of the interior plains. Stockmen and ploughmen may have found meteorites, but generally lacked the interest in unusual rocks characteristic of a prospector.

When the totals in Table 1 are plotted, the rate of increase shows a fairly uniform growth for the period 1897–1966, of about 16 new meteorites per decade, save for the 1913–1923 period; the stagnation in that period may be in part due to the disruption caused by World War I. The remarkable increment of 57 new meteorites since 1966 is almost entirely due to discoveries in Western Australia. This can be ascribed partly to the active involvement of the Western Australian Museum and the Kalgoorlie School of Mines in meteorite search and recovery, and partly to the interest of a group of rabbit trappers working on the Nullabor Plain and criss-crossing it on motor cycles. This is documented in the paper of McCall and Cleverly (1970). They list 36 meteorites from the Nullabor Plain, all but 8 found since 1960; of these 24 were found by members of the Carlisle family!

Until the latest count irons formed the most numerous group of Australian meteorites. This is in marked contrast to the world-wide statistics, and to those for other continental areas (except South America), in which stones predominate over irons. The explanation evidently resides in the desirability of meteoritic iron as raw material for plowshares (and swords) for indigenous metal-working peoples in other continents. Iron meteorites were rapidly consumed once a native people had acquired a facility for metal working, a facility not possessed by the Australian aborigine.

Of the Australian meteorites, ten have been observed falls: Tenham (1879), Emmaville (1900), Binda (1912), Narellan (1928), Karoonda (1930), Forest Vale (1942), Woolgorong (1960), Millbillillie (1960), Wiluna (1967), and Murchison (1969). This gives a ratio of falls to finds of 1 : 16, compared to a ratio of 1 : 5 for the U.S. Clearly this is a reflection of the sparse population of Australia compared to the U.S., and its concentration in limited areas close to the southern and eastern seaboards

The geographical distribution of Australian meteorites also presents some intriguing features. Almost half of Australia lies north of the Tropic of Capricorn, yet only about a dozen meteorites have been found in this vast area. True, much of it is essentially uninhabited, and tropical weathering and dense vegetation in the

far north is unfavourable to the survival and finding of meteorites. Clearly a reasonably close pattern of settlement, and probably ready access to a museum or geological survey or university is conducive to the recovery of meteorites. Special circumstances, typified by the rabbit trappers on the Nullabor Plain, may be an important factor; yet there have been many areas of active rabbit trapping that have yielded nothing. The Nullabor Plains experience resulted from the fortunate coincidence of interest on the part of the trappers encouraged and developed by personnel at the Kalgoorlie School of Mines. A curious lacuna on the meteorite map of Australia is the state of Queensland—almost a quarter of the area of the continent, but fewer than a dozen meteorites are known from the state, and four of these were found in the extreme south, close to the border with New South Wales.

IRONS AND STONY-IRONS

Nickel contents are available for the metal phase in most Australian irons and stony-irons. Lovering et al. (1957) provided data for 39 of these meteorites, and Wasson, in a series of papers, has presented figures for 46. Many meteorites appear in both lists. Lovering et al. determined nickel by the classical wet-chemical procedure, whereas Wasson has used atomic absorption spectrometry. Comparison of analyses of the same meteorites shows that the results of Lovering et al. are consistently a little higher than those of Wasson. For a few meteorites an independent check is provided by the work of Lewis and Moore (1971); their results are generally very close to those of Lovering et al. on the same meteorite. On this account the nickel percentages given by the latter are preferred in Table 2. The data are plotted on figure 1 to illustrate the grouping by chemical composition.

The following irons and stony-irons have not been analysed: Blue Tier (Om), Castray River (iron), Donnybrook (M), Dorrigo (O), King Solomon (iron), Landor (Of), Lefroy (iron), Mt Dyrring (P), Murchison Downs (Off), and Rawlinna (P). The analysis of Mt Sir Charles (Reed, 1972) is not included in Table 2, because the Ni value (6.8%) is clearly inconsistent with the structure (Of); probably a mislabelled specimen was analysed.

Because of geographic propinquity and similarity in composition and structure the following are considered to be paired meteorites:

Barraba and Warialda with Bingera.

Gosnells with Mt Dooling.

Queensland with Gladstone.

Mooranoppin, Mt Stirling, and Quairading with Youndegin.

Loongana Station, Loongana Station West, and Premier Downs with Mundrabilla.

Basedow Range with Henbury.

Hart Range with Boxhole.

In addition, the specimens of Nutwood Downs, reported to have come from a station of that name near Daly Waters in the Northern Territory, are so similar to Henbury that they are considered identical until additional evidence to the contrary is forthcoming. My own inquiries in 1971 to the manager of Nutwood Downs station brought the reply that he knew of no meteorite having been found on the station. Dr J. Wasson (pers. comm.) has analysed specimens of Nutwood Downs, and finds that they are indistinguishable from Henbury in Ni, Ga, Ge, and Ir contents, and notes that they have the same deformed structure.

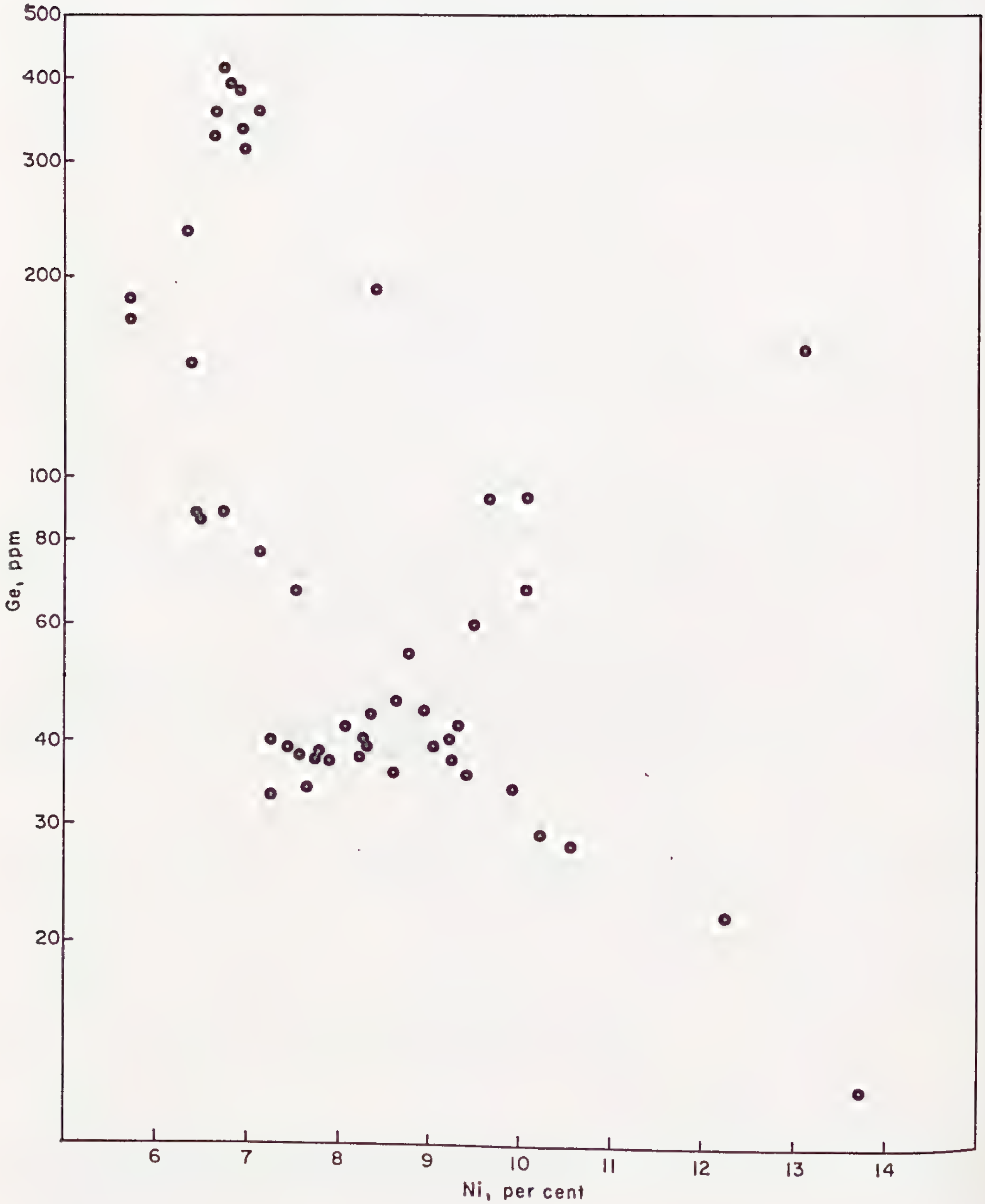

Fig. 1.—Ni (%)—Ge (ppm) plot of Australian iron and stony-iron meteorites, excluding those with less than 10 ppm Ge (Yardea, Moonbi, Boogaldi, Mt Magnet, Warburton Range, Tawallah Valley, Wedderburn)

ACHONDRITES

Relatively few anchrodites have been recorded from Australia. They are: Mt Egerton (enstatite achondrite); Dingo Pup Donga, North Haig (ureilites); Emmaville, Millbillillie (eucrites); and Binda (howardite). The relative paucity of these meteorites can be ascribed to the difficulty of recognition, unless actually seen to fall. They are often rather coarse-grained and friable, and thus tend to break up more readily on weathering than other meteorite types.

Mt Egerton is here considered to be an enstatite achondrite, although it was described by McCall (1965) as a unique type of stony-iron. However, he based his description on about 250 g of fragments from the original find in 1941. The rediscovery of the original site, and the subsequent collection of 19 kg of material by M. K. Quartermaine and A. E. Bain in 1966, and of 8 kg by E. P. Henderson and the writer in 1967, provided the opportunity for a more comprehensive account (Cleverly, 1968). The Mt Egerton meteorite evidently consisted of a poorly coherent aggregate of coarsely crystallized enstatite (crystal fragments up to 7 cm long have been found) with interstitial slugs of nickel-iron, which broke up into innumerable fragments on impact. From bulk density measurements Cleverly estimated the metal content of the meteorite as 21% by weight. This is an exceptionally high metal content for an achondrite, although the Shallowater enstatite achondrite contains about 10% of metal. The similarities in composition, both of metal and silicate, between Mt Egerton and Shallowater strongly favor their being placed together in the same meteorite class.

The only silicate mineral previously recorded from Mt Egerton is enstatite; however, I found a few grains of diopside in some thin sections. Microprobe analyses gave 22.8% CaO in the diopside and 0.4% CaO in the enstatite; if the two minerals crystallized in equilibrium, as the texture suggests, the calcium distribution corresponds to equilibration at about 1000°C, according to the data of Boyd and Schairer (1964).

One of the most remarkable meteorite discoveries of recent years was the finding of two ureilites within a small area on the Nullabor Plain in Western Australia. This almost doubled the total number of ureilites known at that time, from three to five. The two Australian ureilites are North Haig, found by R. F. Kilgallon in 1961, and Dingo Pup Donga, found by A. J. Carlisle in 1965. After their identification as ureilites, it was naturally thought that they might be two pieces of a single fall; however, chemical and mineralogical differences appear to rule out this possibility, and we thus have the statistically improbable occurrence of two meteorites of a rare type falling within 20 miles of each other.

North Haig and Dingo Pup Donga were described by McCall and Cleverly (1968), with chemical analyses by E. Jarosewich and W. R. O'Beirne. The analyses showed appreciable amounts of carbon (4.10% in North Haig and 3.10% in Dingo Pup Donga), and Vdovykin (1970) has established that some of this carbon is present as diamond, as in the other ureilites; he also identified lonsdaleite, the wurtzite structure polymorph of carbon, in North Haig. He divided the ureilites into two types, the Novo-Urei and Goalpara types, on the basis of the olivine structure, coarse-grained in Novo-Urei and fine-grained in Goalpara, and classes Dingo Pup Donga with Novo-Urei and North Haig with Goalpara.

Other features also serve to distinguish these two ureilites. The pyroxene content is notably lower in North Haig than in Dingo Pup Donga. Jarosewich (pers. comm.) found 34.1% acid-insoluble in Dingo Pup Donga and 18.9% in North Haig, and these figures are essentially a measure of the pyroxene content of the meteorite, since the other minerals except carbon are acid-soluble, and the carbon was largely removed by ignition before weighing. Calculations of normative pyroxene from the published analyses give 37.6% in Dingo Pup Donga and 22.7% in North Haig. These figures are consistent with the acid-insoluble figures, and with estimates from the examination of thin sections. Optically, the pyroxenes in the two meteorites are distinctly different; in Dingo Pup Donga the pyroxene shows coarse polysynthetic twinning (which caused it to be originally misidentified as calcic plagioclase), whereas in North Haig most of the pyroxene is untwinned.

Although the chemical analyses of the two meteorites are rather similar, the chemical compositions of the olivine and pyroxene, determined by microprobe analysis, are distinctive.

	Olivine		Pyroxene					
	Range	Mean	Range			Mean		
	Fa	Fa	Wo	Fs	En	Wo	Fs	En
1.	14.0–14.9	14.6	4.1–4.5	14.0–14.9	80.8–81.8	4.3	14.6	81.1
2.	7.8–24.5	14.9	0.4–7.1	0.6–15.1	79.8–99.0	4.0	9.0	87.0

Thus the compositions of these minerals are very uniform from grain to grain in Dingo Pup Donga, in contrast to a wide variation in North Haig. This is further evidence for the belief that these meteorites represent two distinct falls.

A brief discussion on the relationship of the ureilites to other classes of meteorites may perhaps be included here. The ureilites are usually included as a class of the calcium-poor achondrites, since they are stony meteorites which lack chondrules, and the calcium content is low, generally less than 1%. However, they are unique among all stony meteorites in containing diamond. Among the calcium-poor achondrites, the only one resembling them in chemical and mineralogical composition is the unique meteorite Chassigny; however, the structure of Chassigny is quite distinctive (it resembles a terrestrial dunite), and the olivine and pyroxene are much more iron-rich. Some researchers have argued for a close relationship between the ureilites and the carbonaceous chondrites, and indeed Vdovykin (1967) and Mueller (1968) have concluded that ureilites formed from carbonaceous chondrites through the collision of asteroids. While this conclusion provides a satisfactory explanation for the formation of diamonds, it demands a remarkable degree of fractionation of the major elements which seems unlikely to be produced by impact alone. For example, the Mg/Si ratio (weight) averages 1.15 for the ureilites, 0.93 for the carbonaceous chondrites (Type I), and relative to the carbonaceous chondrites the ureilites are notably depleted in Al, Na, Ni and S. Sulphur, being readily volatilized, might be lost in an impact process, but it is difficult to explain the selective loss of Al, Na, and Ni, and the fractionation of the lithophile elements magnesium and silicon.

The calcium-rich achondrites from Australia comprise Millbillillie, Binda, and Emmaville. Millbillillie was evidently an observed fall in 1960, although no material was collected until 1970; it is being described by Dr R. A. Binns. Binda was found on June 5, 1912, following a bright fireball on the night of May 25. Anderson and Mingaye (1913), who described the meteorite, commented "It is not absolutely certain that the stone found is actually that seen in flight on 25th May, but circumstantial evidence is strongly in favour of this being the case". Actually, the freshness of the stone leaves no doubt in my mind that Binda should be classed as an observed fall. Binda is a typical howardite, and the analysis by Mingaye is in excellent agreement with the observed mineralogy. However, his figure for K_2O (0.13%) is probably too high, since recent analyses of howardites and eucrites consistently show very low potassium contents, of the order of 300 ppm. Duke and Silver (1967) give a modal analysis of Binda—75% hypersthene (average Fs_{32}), 25% plagioclase (average An_{90}), $<1\%$ accessories (chromite, ilmenite, troilite, nickel-iron), no olivine or free silica. The trace amount of nickel-iron is kamacite with an unusually high Co content; Lovering (1964) gives probe analyses showing $Ni = 0.44 — 2.10\%$, $Co = 1.38 — 2.22\%$. My own examination of this meteorite agrees with that of Duke and Silver except that I found a few grains of tridymite ($n = 1.474$) in a light ($D < 2.5$) fraction. The meteorite has a cataclastic, brecciated structure, with pyroxene clasts up to 3 mm in greatest dimension, and plagioclase clasts up to 1 mm; the plagioclase clasts show deformed twin lanellae. Pyroxene is mostly hypersthene, often showing thin exsolution lamellae of augite; a few grains of pigeonite were seen. Some or all of the hypersthene could be inverted pigeonite. Microprobe analyses of the pyroxene gave compositions ranging from Fs_{33} to Fs_{36}, with a mean of Fs_{35}, slightly higher than found by Duke and Silver.

Emmaville is a small (99 g) undescribed stone. It fell in 1900 and was recorded by Anderson (1913) in the Australian Museum collection. I saw it there in 1963 and recognized it as probably a eucrite from its characteristic black glossy fusion crust. Petrographic examination of a small fragment confirmed this diagnosis. It is a granular aggregate of calcic plagioclase and pyroxene (mostly pigeonite); it is unusually fine-grained for a eucrite, the maximum grainsize being about 0.1 mm. A notable feature is the presence of veinlets of brown glass, up to 0.2 mm wide, giving the section a brecciated appearance. At my request, Dr A. L. Graham took a 1.5 mg sample, fused it with lithium borate flux, and made a microprobe analysis of the bead produced; his results are: SiO_2 52.6, TiO_2 0.66, Al_2O_3 12.2, Cr_2O_3 0.36, FeO 18.5, CaO 10.2, MgO 6.12, Na_2O 0.51, K_2O 0.03, sum 101.2. The analysis is very similar to that of the Haraiya eucrite (Allen and Mason, 1973), except that the SiO_2 figure is about 4% higher; in view of the small amount of sample and the technique used, an error of this extent in the SiO_2 value is understandable.

CHONDRITES

As mentioned in the introduction, the number of Australian chondrites has greatly increased in recent years, largely because of greater interest by museums in meteorites, and by the activities of rabbit trappers on the Nullabor Plain. Thanks to the cooperation of the local curators, I have received samples of most of those meteorites for examination. As standard procedure, I have obtained polished thin sections of these samples, studied them petrographically, and analysed the olivine and pyroxene with the microprobe. The results are presented in Table 3.

In Table 3 the co-ordinates are, as far as possible, the actual recovery site; however, in some instances the available information is insufficient for precise location. The class has been determined from the olivine composition. The type (Van Schmus and Wood, 1967) has been established by microscopic examination of thin sections, independently by a research assistant and myself; complete agreement was found in about 90% of the meteorites, and for the remainder the difference was not more than one unit; disagreement with previous investigators is recorded in specific notes. The Fa and Fs figures for olivine and pyroxene are given to one decimal place; however, variations within the meteorite, and experimental uncertainty, render the decimal figure of doubtful utility.

The Fa and Fs data are plotted on figure 2, which illustrates the marked compositional break between H and L groups, and the minor break between L and LL groups. The points for most of the chondrites cluster closely along the line joining the extreme compositions (for Cocklebiddy and Lake Labyrinth). The meteorites that fall markedly off this line are the Type 3 or unequilibrated chondrites. Their composition points all fall well below the line, that is, the average pyroxene composition is considerably lower in Fs content than that in equilibrated chondrites of equivalent composition. The pyroxene in these unequilibrated chondrites is exclusively clinobronzite or clinohypersthene, whereas in the equilibrated chondrites it is mainly orthopyroxene. In addition to the difference in iron content, the clinobronzite and clinohypersthene differ from the corresponding orthopyroxene in having a lower calcium content; probe analyses show an average of 0.4 mole per

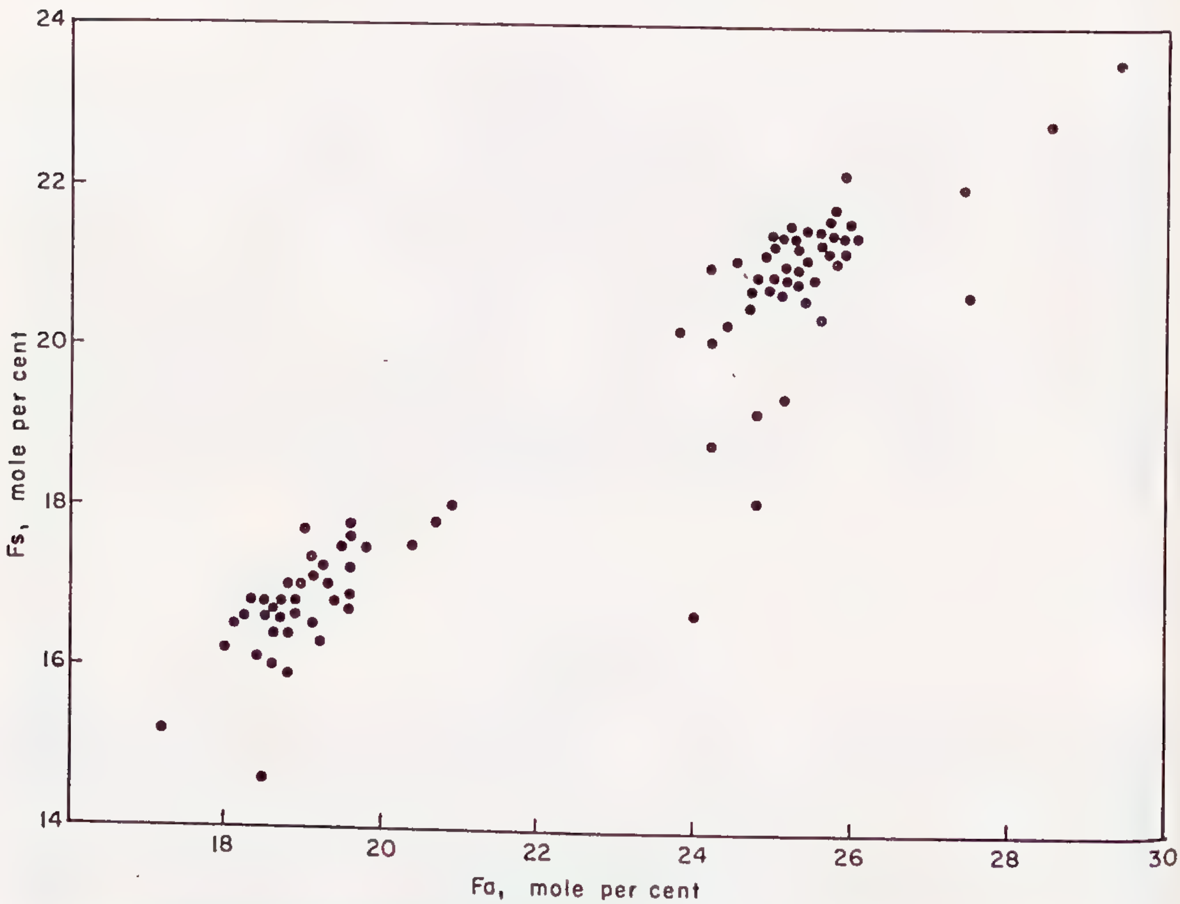

Fig. 2.—Mean values of olivine (Fa) and pyroxene (Fs) composition in Australian chondrites

cent $CaSiO_3$ in the clinobronzite and clinohypersthene, compared to an average of 1.4 mole per cent $CaSiO_3$ in orthopyroxene in the equilibrated chondrites. If equilibrated chondrites have been derived from unequilibrated chondrites by thermal metamorphism, as has been proposed, extensive diffusion of calcium into the pyroxene must have occurred; the most probable source of this calcium would be the interstitial glass characteristic of the unequilibrated chondrites.

There are probably a sufficient number of Australian chondrites in the H and L groups to provide a statistically valid comparison with worldwide occurrences of these meteorites. Such a comparison is provided in Table 4, in which the numbers of these meteorites in Table 3 are compared with the numbers given by Van Schmus and Wood (1967). The agreement between the two sets of numbers is interesting in confirming the validity of the statistical distribution, and supports the utility of the Van Schmus-Wood classification, in spite of the somewhat arbitrary and subjective criteria for distinguishing between adjacent types.

Some notes on individual chondrites follow.

Barratta: This meteorite was classified L4 by Van Schmus and Wood (1967). However, sections I have examined show transparent pink glass in many chondrules, and the pyroxene is entirely polysynthetically twinned clinobronzite and clinohypersthene of highly variable composition (Fs_{14}—Fs_{22}, mean Fs_{17}); these properties are characteristic of Type 3 chondrites.

Bond Springs: The description (Baker and Edwards, 1941) mentions that plagioclase was observed in a thin section, suggesting that this is a Type 6 chondrite.

Carraweena: Two other meteorites from this area, Accalana and Monte Colina, are petrologically identical with Carraweena. Since they belong to the relatively rare L3 Type, it is reasonable to conclude that they are all pieces of the same fall. Heymann (1965), from the similarity in rare gas contents, deduced that Accalana and Carraweena are parts of the same meteorite.

Cartoonkana: This meteorite and Yandama are indistinguishable petrologically, and come from the same area in northwestern New South Wales, close to the South Australian border. There are thus reasonable grounds for considering them as pieces of a single meteorite. However, they belong to the common L6 Type, so the evidence is not as conclusive as for the Carraweena group.

Cockburn: This meteorite was described by Johnson and McColl (1967) on a 10-gram specimen found by Mr Johnson. Four small pieces, totalling some 200 grams, were found by repeated collecting. In July 1973 I visited the area and found two additional specimens, one of 2207 grams and one of 53 grams. Cockburn is an L6 chondrite, with a recrystallized texture and small areas of clear plagioclase grains.

Coolamon: This meteorite contains ringwoodite, a spinel of olivine composition, the third record of this mineral (the previous records are from the Australian chondrites Tenham and Coorara). As in the prior occurrences, the ringwoodite occurs as small (up to 0.1 mm) purple grains in a veinlet traversing the meteorite (plate 6). The material of the veinlet is colorless and isotropic, and is probably majorite, the garnet analogue of pyroxene. Microprobe analyses, using the corresponding minerals in the Coorara meteorite as standards, show that the Coolamon ringwoodite and the vein matrix are essentially identical in composition to the Coorara ringwoodite and majorite. A shock origin is probable for the ringwoodite and majorite, since the meteorite as a whole shows signs of severe shock, specifically the conversion of the plagioclase to maskelynite.

Coorara: McCall and Cleverly (1970) classify it as an L5 chondrite, but thin sections show a recrystallized texture and areas of clear feldspar (transformed to maskelynite), features characteristic of Type 6 chondrites.

Doolgunna: The description (Macleod, 1968) mentions the presence of small clear plagioclase grains, indicating that it is probably a Type 6 chondrite.

Elsinora: A thin section made from a specimen in the Smithsonian Institution collection (USNM #1460, obtained by exchange from the Australian Museum in 1949), shows a very large (5 mm diameter) barred olivine chondrule (plate 7), completely enclosed within the normal-textured chondrite (maximum chondrule diameter approximately 1 mm). Petrographic and probe analyses of the main mass of the chondrite show that it is an equilibrated chondrite with the classification H5. Probe analyses of the large included chondrule show that it is highly unequilibrated; olivine compositions range from Fa_6 to Fa_{19}, with a mean of Fa_{12}. The chondrule appears to consist entirely of olivine, except for the fine-grained interstitial material, which is devitrified to a microcrystalline aggregate, probably pyroxene and plagioclase.

The presence of an unequilibrated chondrule within an equilibrated chondrite raises an intriguing problem of genesis. Van Schmus and Wood (1967), when they established the classification of chondrites by petrographic type, stated "We do believe, however, that the Type 4 chondrites were derived from Type 3 chondrites, and that Types 5 and 6 represent higher degrees of metamorphism". This position has been supported by other investigators, and additional evidence for it adduced by Dodd (1969). However, the presence of a chondrule with highly variable olivine composition within a chondrite with olivine of essentially constant composition is inconsistent with the metamorphism hypothesis. How did the large chondrule avoid equilibration when the main mass of the chondrite was undergoing metamorphism? It does not appear to have been incorporated within the meteorite at a later time, since the specimen in which it occurs shows no sign of brecciation.

In a general paper on olivine composition in chondrites (Mason, 1963), I stated that the Nardoo #1 meteorite was identical with Elsinora. They both come from the same general area northwest of Wanaaring, show a similar degree of weathering, and are of the same type (H5). However, this is the commonest type of H group meteorite, and I now believe they are probably different meteorites and should not be paired.

Hammond Downs: This meteorite was obtained in 1964 as one of a collection of stones from the Tenham fall. However, recent examination has shown that it is a distinct meteorite (Mason, 1973).

Karoonda: The original report states that 42 kg of this meteorite were recovered. However the latest catalogue of the South Australian Museum records only 6.4 kg in that institution, and the British Museum catalogue records less than 2 kg in other institutions. Since this is a unique meteorite with an unusual mineralogy, it is important that all available material be recorded.

During examination of a thin section, a relatively large (0.5 mm diameter) monosomatic olivine chondrule enclosing grains (0.05 mm in maximum dimension) of green isotropic mineral was seen. Probe analyses showed that the green mineral is pleonaste spinel (52 mole per cent $FeAl_2O_4$, 48 mole per cent $MgAl_2O_4$); the olivine composition is Fa_{33}, which is the average for the meteorite as a whole.

Kulnine: While on superficial examination this appears to be a typical L6 chondrite, probe analyses revealed that the orthopyroxene has an unusual composition, being considerably higher in calcium than other chondritic orthopyroxenes. In terms of mole per cent $CaSiO_3$, Kulnine orthopyroxene has a mean content of 3.2%, compared to the usual mean of 1.4%. The texture of the meteorite is also rather unusual; only the vaguest outlines of chondrules can be detected in thin sections, the texture being one of large (up to 1 mm) orthopyroxene crystals in a groundmass of finely granular olivine. The high Wo content of the orthopyroxene suggests a temperature of crystallization higher than for most chondrites. Similar high-calcium orthopyroxene has been recorded from the Shaw chondrite (Fredriksson and Mason, 1967), who postulated as unusually high temperature of crystallization, around 1100°C, for this meteorite.

Laundry East: McCall and Cleverly (1970) classified this meteorite as an H4 chondrite. However, it contains transparent pink glass in some chondrules, and the pyroxene shows the variable composition (Fs_{13}—Fs_{21}) characteristic of Type 3 chondrites.

Laundry West: McCall and Cleverly (1970) classified this meteorite as an L5 chondrite. However, cóndrules are sharply bounded and well-defined, many of them contain turbid partly devitrified glass, and the pyroxene is mostly clinobronzite and clinohypersthene, characteristics indicating classification as a Type 4 chondrite.

Mellenbye: This meteorite and Yalgoo come from the same general region, but the exact place of find for either of them is unknown. I received small fragments of each from the Western Australian Museum, and established that both were LL-group chondrites; olivine composition (by X-ray diffraction) is Fa_{27}. Insufficient material remained for thin sections. In view of their unusual composition (only four other LL-group chondrites are known from Australia) and their geographic propinquity, I believe they are probably different pieces of a single meteorite.

North East Reid: McCall and Cleverly (1970) classified this meteorite as an H4 chondrite. However, in a thin section I have examined chondrule boundaries are diffuse and ill-defined, and no polysynthetically twinned clinopyroxene was seen. On this account a classification as H5 is preferred.

Willaroy: This chondrite was recently found in western New South Wales and is being described by R. O. Chalmers and myself.

Wiluna: This chondrite was classified as a Type 4 by McCall and Jeffrey (1970). However, the advanced degree of integration of chondrules with matrix, the dominance of bronzite over clinobronzite, and the presence of plagioclase all support a classification as Type 5.

ACKNOWLEDGMENTS

I would like to express my appreciation to my companions on extensive field trips investigating Australian meteorites, Dr E. P. Henderson, of the Smithsonian Institution, and Mr R. O. Chalmers, of the Australian Museum. I am indebted to the curators of meteorite collections in the Australian Museum, the National Museum of Victoria, the South Australian Museum, the Kalgoorlie School of Mines, and the Western Australian Museum for research material. Miss Camille Calabro assisted me in the petrographic and microprobe analyses. Field work was supported by grants from the National Geographic Society and the Smithsonian Research Foundation. Additional information and critical reviews of the manuscript have been provided by Mr R. O. Chalmers and Dr S. J. B. Reed.

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Table 1. Australian meteorites in collections, 1897–1973

References	Irons	Stony-Irons	Stones	Total
Cooksey, 1897	15	..	4	19
Anderson, 1913	29	4	13	46
Prior, 1923	29	4	15	48
Hodge-Smith, 1939	45	8	24	77
Prior-Hey, 1953	52	8	35	95
Hey, 1966	61	8	57	126
This paper	67	9	108	184

Table 2. Australian irons and stony-irons and their structural type and Ge-Ga classification

Meteorite	Ni%	Ge, ppm	Structural Type	Ge-Ga Class	References
Alikatnima	13.0	<3	D	Anom	3
Answer	12.5		D		5
Arltunga	10.08	68	D	Anom	1
Avoca	8.65	46	Om	III A	11
Balfour Downs	8.39	194	Og	I	4
Ballinoo	10.06	94.4	Off	II C	1, 4
Bencubbin	6.20		Anom		2
Bendock	9.20	40	P		1
Bingera	5.71	185	H	II A	1, 4
Boogaldi	8.99	0.132	Of	IV A	1, 4
Boxhole	7.72	37.2	Om	III A	1, 4
Coolac	6.95	335	Og	I	1
Corowa	13.13	159	D	Anom	4
Cowell	8.2	38	Om	III A	3
Cowra	13.72	12.3	Opl	Anom	1, 4
Cranbourne	7.12	358	Og	I	1, 4
Dalgaranga	8.79	54.6	M		4
Delegate	9.34	41.7	Om	III B—Anom	1, 4
Duketon	7.52	38.1	Om	III A	4
Gladstone	6.74	418	Ogg	I	1, 4
Glenormiston	7.12	76.8	Anom	Anom	1, 4
Gundaring	8.32	43.9	Og	III A	1, 4
Haig	7.24	32.8	Om	III A	4
Henbury	7.66	33.7	Om	III A	1, 4
Huckitta	8.98		P		12
Kumerina	9.69	93.4	Of	II C	4
Kyancutta	8.28	39.5	Om	III A	1, 4
Lismore	7.79		Om		9
Milly Milly	7.45	38.6	Om	III A	4
Molong	8.61		P		10
Moonbi	7.99	0.826	Om	III F	1, 4
Moorumbunna	8.98	44	Om	III AB	4
Morden	6.6	329	H	I	3
Mt Dooling	6.41	234	Ogg	I—Anom	1, 4
Mt Edith	9.40	35.7	Om	III B	1, 4
Mt Magnet	14.72	5.26	Opl	Anom	1, 4
Mt Padbury	7.18		M		6
Mundrabilla	7.78		Om		8

Table 2. Australian irons and stony-irons and their structural type and Ge-Ga classification—*continued*

Meteorite	Ni%	Ge, ppm	Structural Type	Ge-Ga Class	References
Mungindi	12.27	22.1	Of	III C	1, 4
Mirnpeowie	6.47	85.4	Anom	Anom	1, 4
Narraburra	10.22	28.7	Om	III B	1, 4
Nocoleche	6.42	148	Anom	Anom	1, 4
Nuleri	7.32		Om		7
Pinnaroo	9.50	60	M		1
Redfields	6.65	93	Anom	Anom	8
Rhine Villa	8.63	36.3	Og	III E	4
Roebourne	8.40	42.4	Om	III A	1, 4
Roper River	9.91	33.9	Om	III B	1, 4
Tawallah Valley	18.21	0.068	D	IV B	1, 4
Temora	6.66	355	Ogg	I	1
Thunda	8.27	38.9	Om	III A	1, 4
Tieraco Creek	10.55	28.0	Om	III B	1, 4
Warburton Range	17.80	0.064	D	IV B	4
Wedderburn	22.2	1.43	D	IV	1, 4
Weekero	7.51	67.0	Anom	Anom	4
Wolf Creek	9.22	37.3	Om	III B	4
Wonyulgunna	9.05	39.6	Om	III B	1
Yardea	7.7	8	Om	Anom	3
Yarri	7.77	38.5	Om	III A	4
Yarroweyah	5.70	171	H	II A	1, 4
Yenberrie	6.97	312	Og	I	1, 4
Youanmi	7.85	37.7	Om	III A	4
Youndegin	6.92	383	Og	I	1, 4

References to Table 2:

1. Lovering et al. (1957). 2. Simpson and Murray (1932). 3. Reed (1972). 4. Wasson (1970) and pers. comm. 5. Houston (1971). 6. Jarosewich (pers. comm.). 7. Cleverly and Thomas (1969). 8. de Laeter et al. (1973). 9. Edwards (1960). 10. Mingaye (1916). 11. McCall (1968). 12. Madigan (1939).

Table 3. Geographical coordinates, classification, and compositions of coexisting olivine and pyroxene in Australian chondrites

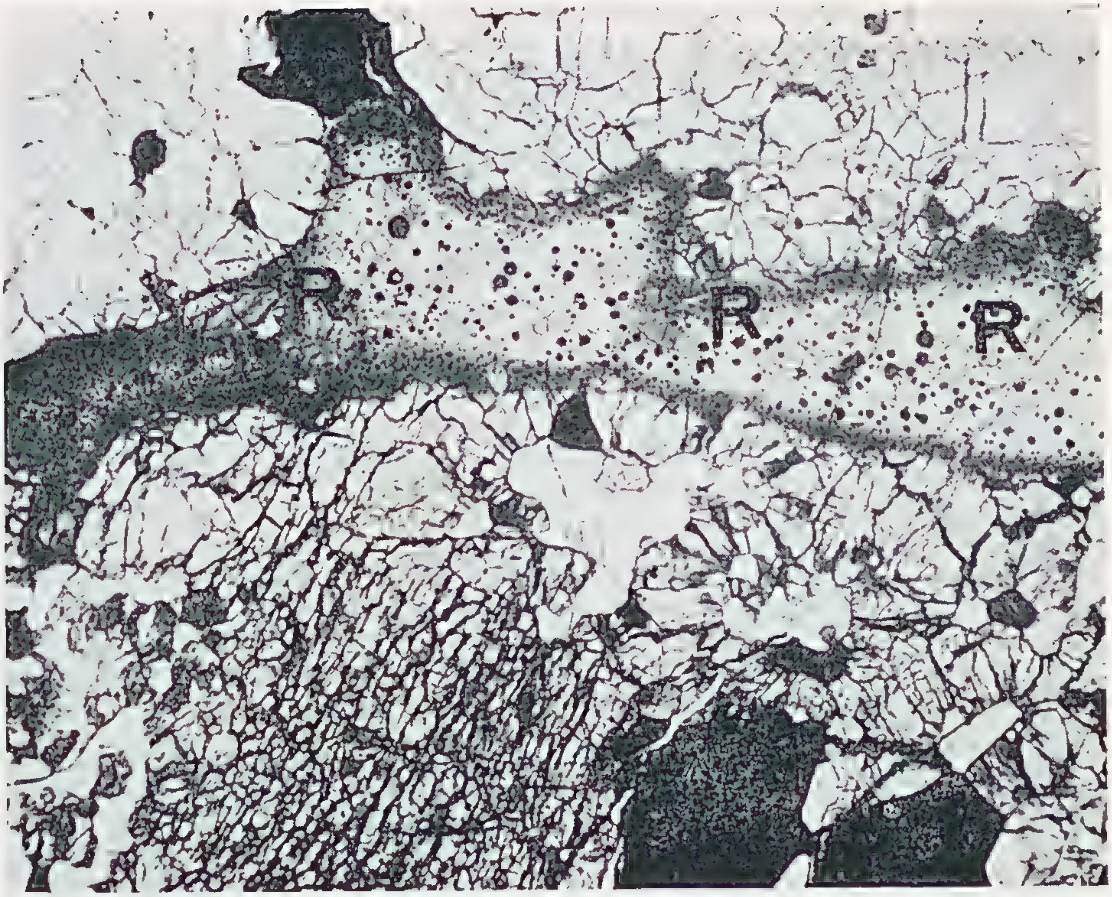
Name	Coordinates		Class and Type	Fa	Fs
Artracoona	29° 04′	139° 55′	L6	25.6	20.4
Baandee	32° 37′	118° 02′	H		
Barratta	35° 18′	144° 34′	L3	24.0	16.7
Billygoat Donga	30° 08′	126° 22′	L6	25.1	21.4
Bond Springs	23° 33′	133° 54′	H		
Burnabbie	32° 03′	126° 10′	H5	18.5	16.6
Burrika	31° 58′	125° 50′	L6	25.0	21.3
Cadell	34° 04′	139° 45′	L6	25.5	20.9
Cardanumbi	32° 10′	125° 38′	L5	25.7	21.5
Caroline	37° 59′	140° 59′	H5	20.9	18.0
Carraweena	29° 14′	139° 56′	L3	24.8	18.1
Cartoonkana	29° 45′	141° 02′	L6	25.7	21.6
Cockarrow Creek	26° 40′	120° 10′	L6	25.4	21.5
Cockburn	32° 08′	141° 02′	L6	25.1	21.4
Cocklebiddy	31° 56′	126° 13′	H5	17.2	15.2
Cocunda	32° 49′	134° 48′	L6	25.8	21.1
Coolamon	34° 49′	147° 08′	L6	25.9	21.4
Coomandook	35° 29′	139° 50′	H6	18.8	17.0
Coonana	29° 51′	140° 43′	H4	19.2	16.3
Coorara	30° 27′	126° 06′	L6	25.9	22.2
Credo	30° 22′	120° 44′	L6	24.9	21.2
Crocker Well	32° 01′	139° 47′			
Dalgety Downs	25° 20′	116° 11′	L5	25.2	21.4
Dimboola	36° 30′	142° 02′	H5	19.4	16.8
Doolgunna	25° 56′	119° 18′	L		
Edjudina	29° 35′	122° 11′	H4	18.7	16.6
Eli Elwah	34° 30′	144° 43′	L6	25.3	21.0
Ellerslie	28° 54′	145° 53′	L5	25.2	20.9
Elsinora	29° 27′	143° 36′	H5	19.8	17.5
Fenbark	30° 26′	121° 15′	H5	19.6	16.7
Forest Vale	33° 21′	146° 51′	H4	18.6	16.0
Forrest	30° 49′	128° 13′	H5	19.6	17.6
Forrest Lakes	29° 25′	129° 30′	LL5	27.5	20.7
Frenchman Bay	30° 36′	115° 10′	H3	18.5	14.6
Gilgoin	30° 23′	147° 12′	H5	18.0	16.2
Gunnadorah	31° 00′	125° 56′	H5	19.1	16.5
Hamilton	28° 29′	148° 15′	L6	25.3	20.8
Hammond Downs	25° 28′	142° 48′	H4	18.8	16.4
Hermitage Plains	31° 44′	146° 30′	L6	25.6	21.3
Jeedamya	29° 35′	121° 10′	H6		
Kaldoonera Hill	32° 37′	134° 51′	H6	18.7	16.8
Kappakoola	33° 15′	135° 32′	H6	19.6	17.2
Karoonda	35° 06′	139° 56′	C4	32.5	
Kielpa	33° 36′	136° 06′	H5	18.9	17.0
Kingoonya	30° 57′	135° 24′	L4	23.8	20.2
Kittakittaooloo	28° 02′	138° 08′	H4	18.9	16.8
Koraleigh	35° 06′	143° 24′	L6	26.0	21.4
Kulnine	34° 09′	141° 47′	L6	25.4	20.6
Kybunga	33° 54′	138° 29′	L5	25.0	21.4
Lake Bonney	37° 45′	140° 18′	L6	24.5	21.1
Lake Brown	31° 00′	118° 30′	L6	25.0	20.9
Lake Grace	33° 04′	118° 13′	L6	25.9	21.2
Lake Labyrinth	30° 33′	134° 45′	LL6	29.4	23.6
Laundry East	31° 31′	127° 08′	H3	18.5	16.8
Laundry Rockhole	31° 32′	127° 01′	H5	20.4	17.5
Laundry West	31° 28′	126° 56′	L4	24.2	18.8
Mellenbye	28° 51′	116° 17′	LL	27	

Table 3. Geographical coordinates, classification, and compositions of coexisting olivine and pyroxene in Australian chondrites—*continued*

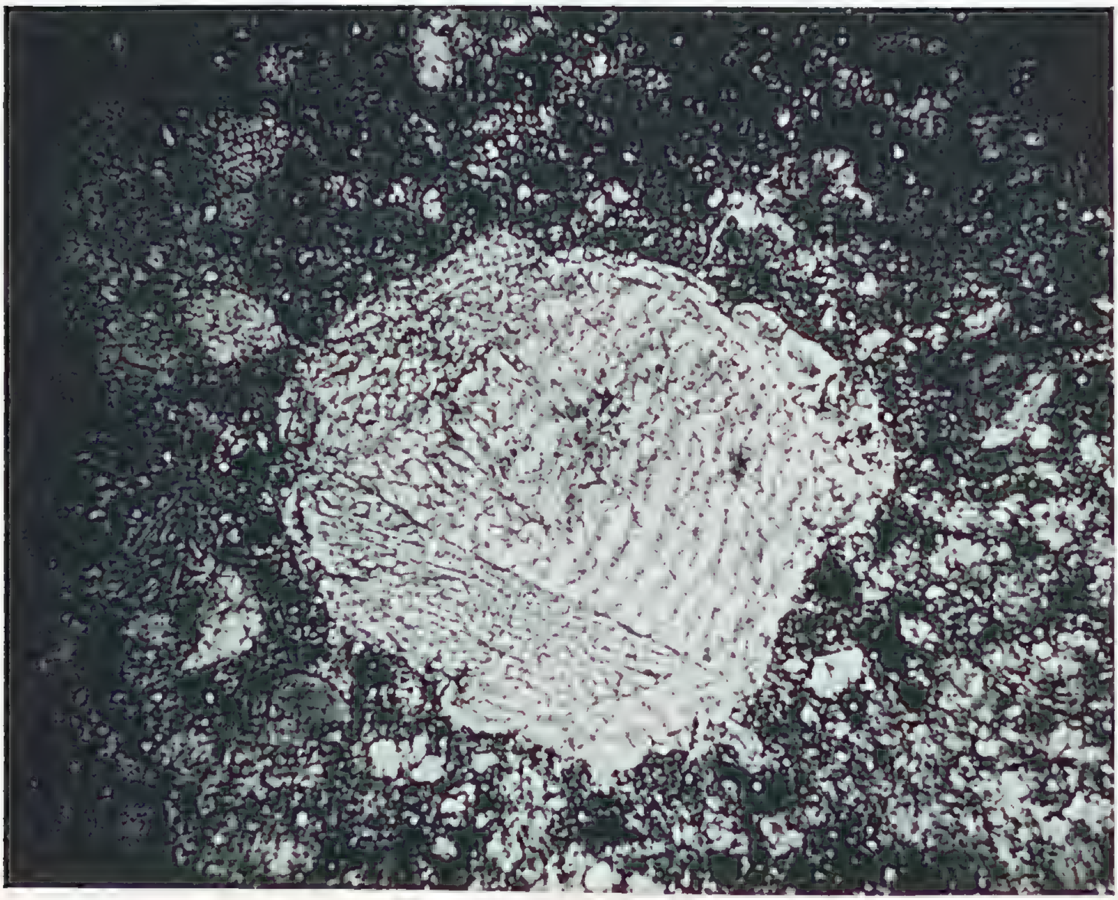
Name	Coordinates		Class and Type	Fa	Fs
Moorleah	40° 59′	145° 36′	L6	24.4	20.3
Mossgiel	33° 19′	144° 47′	L4	24.2	20.1
Motpena	31° 06′	138° 16′	L6	25.8	21.7
Mt Browne	29° 48′	141° 42′	H6	18.1	16.5
Mulga (north)	30° 11′	126° 22′	H6	19.3	17.0
Mulga (south)	30° 12′	126° 22′	H4	18.4	16.1
Mulga (west)	30° 11′	126° 22′	C4		
Murchison	36° 40′	145° 14′	C2		
Nallah	31° 58′	126° 15′	H	18	
Nardoo #1	29° 32′	143° 59′	H5	18.8	15.9
Nardoo #2	29° 30′	144° 04′	L6	25.0	20.9
Narellan	34° 03′	150° 41′	L6	25.3	21.4
Naretha	31° 00′	124° 50′	L4	24.8	19.2
Nora Creina	37° 19′	139° 51′	L4	25.1	19.4
North East Reid	30° 09′	128° 43′	H5	18.6	16.6
North Forrest	30° 30′	128° 06′	H4	19.1	17.1
North Reid	30° 08′	128° 38′	LL5	27.4	22.0
North West Forrest	30° 36′	127° 49′	E6		0.3
Oak	31° 35′	127° 42′	L5	25.7	21.2
Pannikin	32° 02′	126° 11′	L6	24	
Pevensey	34° 45′	144° 40′	LL5	28.5	22.8
Rawlinna	30° 22′	126° 05′	H5	19.4	16.8
Reid	30° 11′	128° 41′	H	18.4	16.9
River	30° 22′	126° 01′	L5	24.7	20.9
Rowena	29° 48′	148° 38′	H6	19.5	17.6
Silverton	31° 53′	141° 12′	L6	25.4	21.0
Sleeper Camp	30° 15′	126° 20′	L6	24.7	20.6
Tenham	25° 38′	142° 50′	L6	25.1	20.8
Ularring	29° 58′	120° 36′	L6	25.6	21.5
Vincent	35° 01′	139° 56′	L5	24.2	21.0
Webb	31° 45′	127° 47′	L6	25.3	21.4
West Forrest	30° 40′	127° 50′	H5	18.7	16.7
West Reid	30° 11′	128° 40′	H6	19.6	17.7
Wilbia	26° 27′	131° 00′	H5	19.0	17.7
Wildara	28° 14′	120° 51′	H5	20.7	17.9
Willaroy	30° 06′	143° 12′	H3	14.6	14.5
Wiluna	26° 36′	120° 20′	H5	19.2	17.2
Wingellina	26° 04′	128° 57′	H4	18.2	16.6
Witchellina	30° 00′	138° 00′	H4	19.1	17.3
Woolgorong	27° 45′	115° 50′	L6	25.2	21.0
Wynella	28° 57′	148° 08′	H4	18.7	16.4
Yalgoo	28° 23′	116° 43′	LL	27	
Yandama	29° 45′	141° 02′	L6	25.0	20.9
Yayjinna	32° 02′	126° 10′	L6	26.0	21.6
Yilmia	31° 12′	121° 32′	E6		

Table 4. Numbers and percentages of Australian chondrites in H and L groups and types, compared with the worldwide data on Van Schmus and Wood (1967)

	Australian		Worldwide	
	Number	Per cent	Number	Per cent
H3	3	3	7	2
H4	10	12	35	9
H5	19	22	74	19
H6	8	9	44	12
L3	2	2	9	2
L4	5	6	18	5
L5	7	8	43	11
L6	32	38	152	40
Total	86	100	382	100



Veinlet (maximum width 0.2 mm) of majorite, with grains of ringwoodite (R), in the Coolamon meteorite. [Photo: Smithsonian Institution].



Large (5 mm diameter) unequilibrated olivine chondrule in the Elsinora meteorite. [Photo: Smithsonian Institution]

A New Leech from Papua, Representative of a Third Family of Aquatic Jawed Sanguivores in the Australian Region (Hirudinoidea: Illebdellidae fam. nov.)[1]

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Figure 1

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ABSTRACT

A new family based on *Illebdella papuensis* gen. et sp. nov. is described. Characters include: body strongly depressed and wide; monostichodont, trignathous; pharynx euthylaematous with single secondary ridges in the dorsolateral positions; epididymis, a globular mass at xi/xii; no sperm ducts or ejaculatory bulbs; median regions, bimyomeric; vagina, caecate; no vaginal duct; ix to xxiv, 5-annulate; xxv, 4-annulate; xxvi, 3-annulate. Pattern, topographic, a wide median band of alternating maculae; a lateral catenulate row of large ovals. *Hirudo catenulata* Johansson 1918 is transferred to the new family and provisionally to the g. *Illebdella*.

INTRODUCTION

The leech described here is known from a single preserved specimen collected in 1929 at Mount Lamington in the Northern Division of Papua.

It is strongly depressed, with acute flange-like margins. The pattern consists of a median metamerically checkered band, an inner paired longitudinal row of separated short segmental ovals, and an outer paired row of longer segmental ovals linked at the intersomital levels to be catenulate, chain-like.

Form and pattern indicated that this could not be placed in either of the two established families. This is confirmed in the nature of the pharynx and the form of the anterior region of the male paired duct.

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63216—A

The species of the eleven genera of aquatic jawed sanguivores now known in the Australian Region are only moderately depressed, the margins obtusely rounded. They are divided among two families, the pharynx in both families being of the type which (1969) I termed hirudoid: trignathous; monostichodont; termininating mostly in ix to ix/x, exceptionally at viii/ix; the entrance narrow, the lumen tubular, tapering; internal muscular ridges arranged as dorsomedian and a pair of ventrolaterals, and lacking dorsolaterals and a ventromedian ending independently on the margin of the entrance to the pharynx.

The two families differ:

Ornithobdellidae Richardson 1969.— As so far known lacking a topographically definable pattern; the female pore, posterior at xii/xiii to xiii b_1/b_2; anterior region of the male paired duct folded on itself in a primary loop, the epididymis on the initial limb, a sperm duct on the terminal limb which may or may not carry an ejaculatory bulb, the relationship parallel; median regions of the reproductive system, amyomeric, i.e. thin-walled atria connecting directly to the bursa, micromorphic, minute extending little higher than the ventral nerve cord. gg. *Ornithobdella* Benham 1909, Snares Is., New Zealand; *Aetheobdella* Moore 1935, eastern Australia, Queensland to Victoria.

Richardsonianidae Richardson 1969.—pattern, topographic, longitudinal dark bands separated by stripes of a light contrast colour; female pore, xii b_5/b_6 or immediately adjacent to this; anterior region of the male paired duct linear, an epididymis posterior to an ejaculatory bulb, the relationship, tandem; median regions of the reproductive systems, myomeric i.e. the organs with a wall of well organized muscular layers, bimyomeric (on both), or hemimyomeric (the male, amyomeric); vagina, caecate. gg. *Richardsonianus* Soos 1968; *Goddardobdella* Richardson 1969, Torresian including Papua; *Quantenobdella* Richardson 1969, Lord Howe Is.; *Euranophila* Richardson 1969, Torresian of the west; *Eunomobdella* Richardson 1969, north-eastern N.S.W.; *Bassianobdella* Richardson 1970, Bassian of the east; *Habeobdella* Richardson 1972, Bassian of the west; *Kaiyabdella* Richardson 1972, Torresian of the east; *Priscabdella* Richardson 1973, Bassian of the east.

The leech described here differs from the above not only in form and pattern, but also in the nature of the pharynx and in the morphology of the anterior region of the male paired duct.

The pharynx is of the type I termed macrobdelloid: similar to the hirudoid, but additional to the dorsomedian and ventrolateral primary internal ridges, there are secondary muscular ridges in the dorsolateral (and ?ventromedian) positions, ridges which terminate independently on the margin of the entrance to the pharynx between the bases of the jaws. The anterior region of the male paired duct is linear, with an epididymis complexly folded on itself into a small compact globular mass; no sperm duct; no ejaculatory bulb.

General form, pattern, the nature of the pharynx and of the anterior region of the male paired duct, in combination exclude the Mount Lamington leech from both the Ornithobdellidae and the Richardsonianidae. There is no established family suitable for it.

Hirudo catenulata Johansson 1918 of the New Hebrides, known only in Johansson's incomplete description, can be transferred to the new family and placed at least provisionally in the new genus given below.

SYSTEMATICS

Illebdellidae fam. nov.

Arhynchobdellae; Euthylaemata; pharynx and associated structures, macrobdelloid; fully divided nephric somites 5-annulate; nephropores, ventral; female pore, xii b_5/b_6; anterior region of male paired duct linear, epididymis formed as a compact globular mass; no sperm duct or ejaculatory bulb; median regions of the reproductive systems, myomeric, formed on a posteriorly directed primary loop; vagina, caecate.

Pattern, metameric maculations and catenulations.

Aquatic. Sanguivorous. Australian Region: Papua; New Hebrides.

Type genus: Illebdella gen. nov. as below.

The division of the internal longitudinal muscles of the body wall into two distinct equally well developed layers has not come to my notice in other aquatic jawed sanguivores. The systematic value of this feature cannot be assessed at this time.

This is the first occasion on which the form of the anterior region of the male paired duct in a euthylaematous leech of the Australian Region has some resemblance to a form known in a leech of another Region.

In his account of *Hirudinaria viridis* Moore 1927, a leech of India, Moore (1927, fig. 57) shows the vas deferens forming a globular "epididymal" mass. The vas deferens enters the mass somewhat posteriorly, and the general appearance of the mass suggests that the epididymis has formed on the initial limb of a primary loop, with a sperm duct completing the terminal limb of the loop. I can see no basis for any relationship for *H. viridis* and the leech below.

Illebdella gen. nov.

Derivation: ille = that + bdella = a leech. m.

Description: Illebdellidae; ix to xxiv complete 5-annulate (total, 16); xxv, 4-annulate; somital sense organs, obscure; jaws, small, compressed, tall; no salivary gland papillae on jaws; teeth, small, about 50; dorsal salivary glands, sparse, no obvious columns of aggregated ducts; extrinsic radial muscles of pharynx, an obvious system in vii to in ix; pharynx and associated structures, macrobdelloid; wall of pharynx, thin; internal muscular ridges, thin, primaries not secondarily subdivided, secondaries in the dorsolateral positions, well-formed, single, ending independently on the margin of the entrance to the pharynx; pharynx terminating in ix; crop with a short simple compartment in ix; compartments in x to xviii, each with a pair of caeca in the anterior position and a pair in the posterior position, both entering the paramedian chamber from xiii to xviii, both distally lobed; the compartment in xix with an anterior pair of caeca, and postcaeca originating in the posterior position extending in the paramedian chamber to terminate in xxvi; intestine tubular, acaecate, compartmented, connecting terminally to the rectum; genital pores, posterior in xi b_5 and at xii b_5/b_6; testes, 10 pairs, saccular, the anterior pair at xiii/xiv; anterior region of male paired duct, linear, an epididymis formed as a compact globular mass in the contiguous halves of xi and xii; no ejaculatory bulbs; median regions of the reproductive systems, bimyomeric, mesomorphic, both formed on a posteriorly directed primary loop; penis sheath reflecting in xii; vagina, caecate; no vaginal duct.

Pattern: Metameric maculations and catenulations.

Distribution: Aquatic. Sanguivorous. Australian Region: Papuan.

Type Species: *Illebdella papuensis* sp. nov.

Other species: (Provisionally) *Hirudo catenulata* Johansson 1918, New Hebrides (see below).

Illebdella papuensis sp. nov. (Fig. 1)

Holotype: A specimen 50.0 mm long, dissected. Mt Lamington District, Northern Divison, Papua, May 1929. Collector, C. T. McNamara. Australian Museum, Sydney, reg. no. W.2692.

General Form (Fig. 1A)

Preserved, contracted; strongly depressed, the dorsum very low convex; margins narrowly flange-like, acute; venter very slightly concave. The margins are parallel, straight along the greater length of the body (between 10.0 and 40.0 mm from the tip of the velum) and the width uniform; reducing abruptly in width anterior and posterior to these levels, anteriorly to form a transversely oblong preclitellar region, posteriorly gradually and then abruptly to form the basis for the large posterior sucker.

Total length, 50.0 mm; width at the anterior end, 5.0 mm back to 3.0 mm, then increasing to be 15.0 mm wide at 10.0 mm and of this width back to 40.0 mm, reducing to form the base, 5.0 mm wide, of the posterior sucker which is 9.0 mm wide. The depth almost uniformly 4.0 mm along the mid-line of the body, decreasing gradually laterally to the thin marginal flanges.

Colour

Preserved, faded. Dorsum weakly dusky yellow with faded blackish maculae and linear markings; venter, of the same colour, immaculate.

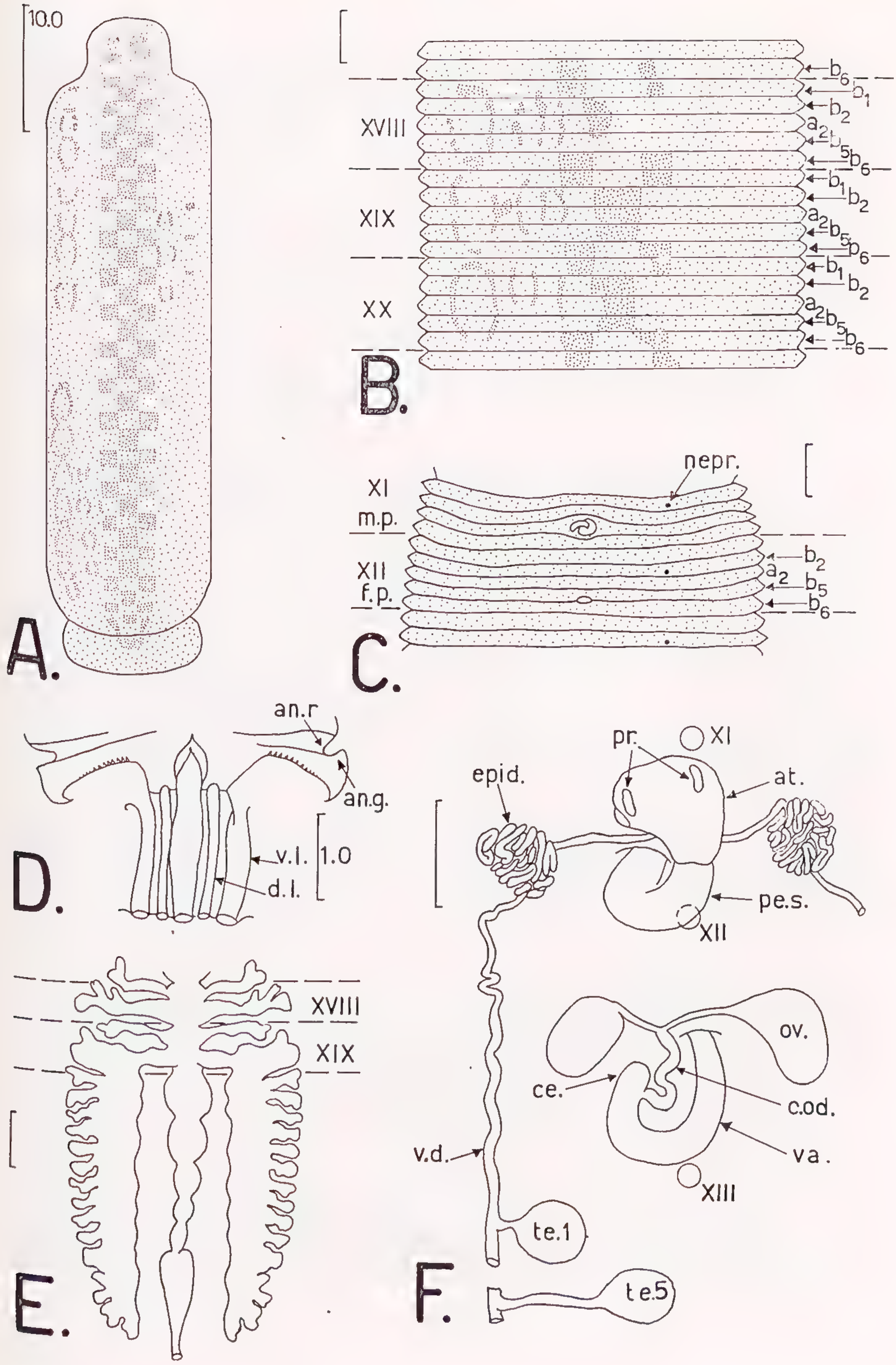
Pattern (Fig. 1, A, B)

Preserved, faded, poorly indicated on the right, sufficiently on the left for description. Somital sense organs are not detectable and, although topographically defined, the pattern cannot be described in full topographic detail.

Dorsum with a median longitudinal row of regularly spaced oblong maculae. On either side of this, a contiguous row of slightly shorter squarish maculae, the squarish maculae alternating with the maculae of the median row, and the three together forming a checkered band along the length of the body.

Opposite

Figure 1. *Illebdella papuensis* gen. et sp. nov. A, dorsal view showing general form and pattern. B, detail of indications of pattern on somites xviii to xx. C, ventral view, somites xi and xii, showing genital pores and nephropores. D, pharynx opened by a median ventral longitudinal incision to show the annular ridge and groove, jaws, internal muscular ridges of the pharynx. E, caecation of crop, somites xviii and xix; intestine; rectum. F, anterior region of male paired ducts, male median region; female reproductive system. All figures from the holotype. Somites and somital ganglia indicated by roman numerals; somital limits, by interrupted lines; annuli, "a_2", etc.; somital ganglia represented at relative size. Scales in mm, 2.0 mm or as indicated. Abbreviations: an.g., annular groove; an.r., annular ridge; at., atrium; c.od., common oviduct; ce., caecum; d.l., dorsolateral muscular ridge; epid., epididymis; f.p., female pore; m.p., male pore; nepr., nephropore; ov., ovary; pe.s., penis sheath; pr., prostate; te., testis; va., vagina; v.d., vas deferens; v.l., ventrolateral muscular ridge.


10.0
A.
XVIII
XIX
XX
b6
b1
b2
a2
b5
B.
nepr.
XI
m.p.
XII
f.p.
C.
an.r
an.g.
v.l.
1.0
d.l.
D.
XVIII
XIX
E.
pr.
XI
epid.
at.
pe.s.
XII
ov.
ce.
c.od.
va.
v.d.
XIII
te.1
te.5
F.

Just lateral to this band, narrow interrupted longitudinal lines appearing as pairs closely approximated anteriorly and posteriorly, divergent along their length, so that they partially, with some few completely enclose individual longitudinal patches at the level of the maculae of the median row of the checkered band. This forms an inner paired row of oval patches.

An outer paired row of similar oval patches is situated between the inner row of such patches and the margin.

The oval patches of the outer paired row are slightly longer than those of the inner paired row, and join at each end into a black patch, linking these oval patches together in a catenulate, chain-like manner.

The above is a metamerically repeated pattern.

In fully annulated somites, the oblong patches of the median row of the checkered band are continuous over b_2, a_2, b_5; the most anterior, transversely oblong on vi and on vii; longitudinally oblong on viii to xxiii; and vaguely indicated in xxiv to xxvii.

The contiguous squarish patches are continuous over b_6 and b_1, the contiguous annuli of fully annulated somites. Each is of the width of the adjacent median patch, and shorter by the length of an annulus; the most anterior, on vii a_2 and a_3, then regularly on b_6 and b_1 from viii and ix, to xxiv and xxv; the most posterior, a pair of elongate patches posterior on xxv, crossing xxvi into xxvii.

The patches of the mid-line are accordingly across the neuromeric and contiguous annuli, central in the somite; the patches of the paired rows, across the contiguous annuli of the intersomital levels.

A narrow longitudinal dark line connects the outer corners of the paired patches across b_2, a_2, b_5 in the somite, i.e. enclosing a patch bordered anteriorly and posteriorly by the paired squared patches, medially by the elongate median patch, and laterally by a line having the same relationship to the annuli in the somite as does the median patch.

Lateral to the median checkered band, there is a row of paired short narrow lines, the anterior ends closely approximated at b_1/b_2, appearing as though possibly joining at this level or posterior on b_1; divergent on b_2, a_2, and covergent on b_5. Under the low power, these appear to be a series of short somital oval areas defined by narrow black borders, and having essentially the same relationship to the annuli in the somite as does the median patch.

Between this paired row of oval patches and the margin, there is an outer row of oval patches, each oval defined by a narrow black border extending across b_2, a_2 b_5 and having the same relationship to the annuli of the somite as does the median patch, and the ovals of adjacent somites linked by a black patch continuous across b_6 and b_1, i.e. the linking patches have the same relationship to the annulation of the somites as do the paired patches of the median checkered band. The ovals of this chain are recognizable from ix back to xxv.

Accordingly the outer paired catenulate row consists of patches having the relationship to the annuli of the somites similar to that of the paired patches of the median checkered band, and ovals defined by narrow borders having the relationship to the annuli of the somite similar to that of the median patches of the checkered band.

The venter is immaculate. The dorsum of the posterior sucker has a black postanal patch.

Annulation

Preserved. Contracted. The annuli on the dorsum strongly compressed, and the relative lengths of the annuli cannot be assessed; interannular and intersomital furrows, equivalent; somital limits not directly recognizable. Somital sense organs not detectable. Nephropores, fully ventral, minute apertures close to the posterior edge of a_1 and b_2, situated nearly midway between the median line and the margin.

Velum turned ventrally to cover the entrance to the sucker. Eyes, obscure. The 1st furrow, iii/iv, is short and does not reach the edge of the velum; iv, 2-annulate, a_1a_2/a_3 does not reach the edge of the velum; iv/v incises the edge of the velum, and v incomplete 2-annulate, a_1a_2 forming the dorsolateral lobe on the margin of the sucker, and uniannulate v forms the lateral and ventral margins, the furrow a_1a_2/a_3 terminates in the dorsolateral lobe; vi, 3-annulate above, 2-annulate below; vii, complete 3-annulate; viii, 4-annulate; ix to xxiv, 5-annulate (total 16); xxv, 4-annulate, $b_1 = b_2 = a_2 < a_3$; xxvi, 3-annulate, $a_1 > a_2 = a_3$; xxvii, uniannulate or possibly a_1, $(a_2 + a_3)$; anus at the posterior edge of xxvii.

Dorsum of the posterior sucker with 7 or 8 concentric rows of areolae; the venter, with a central papillate area about $\frac{1}{2}$ of the diameter of the sucker and radiating muscular bands subdividing to terminate as about 90 at the margin of the sucker.

Body wall and muscular systems

The body wall is unusually firm and thick. The layers of oblique muscle are recognizable as outer and inner layers, and together do not equal the thickness of the internal longitudinal muscles which consist of two layers each of wide (0.35 mm) flat strands anteriorly, both layers here adherent and continuous with the body wall. Posteriorly, the strands increase in width (0.80 mm), the inner layer becomes separated from the outer, and the fibres of the inner lay can be lifted individually as though fully separated from one another. There is a pair of equally wide strands along the mid-dorsal line for the length of the body. This pair is fully adherent to the body wall.

The paramedian palisade of dorsoventral muscles is represented by wide-spaced small clusters at the intersomital levels; the intermediate palisade, by a continuous row of narrowly spaced strands, unusually short as they are at the base of the thin marginal flanges of the body.

Alimentary Tract (Fig. 1, D, E)

The lower surface of the velum is smooth, carries a weak median and several transverse furrows, and ends posteriorly in an annular ridge which is low, poorly formed anterior to the dorsomedian jaw, and increases in height and width on the inner surface of the lateral walls of the sucker. The ridge defines an annular groove which appears incomplete dorsally, is well-formed laterally, and is obliterated by a frenulum in the mid-ventral line. The dorsomedian jaw is housed in a poorly formed pocket; the ventrolaterals, in the annular groove, separated by the ventral frenulum.

The jaws are very small, about 1.8 mm long, strongly compressed to be taller (0.5 mm) than wide (0.25) at the medial end. The dental margin is almost straight, armed with a single row of minute teeth(assessed as about 50 or less), the medial teeth the tallest, the height diminishing more rapidly along the medial end of the row than along the distal portion, so that the greater length of the row has teeth very gradually diminishing in height.

The entrance to the pharynx is distinctly wider than the base of the dorsomedian jaw. The wall of the pharynx is thinly muscular. The internal muscular ridges include the three primaries, a dorsoventral and a pair of ventrolaterals which are not subdivided and enter the base of the appropriate jaw, and a pair of weaker but well-formed dorsolateral ridges which terminate independently on the margin of the entrance to the pharynx on either side of the base of the dorsomedian jaw. A ventromedian was not recognizable.

The lumen of the pharynx is tapering tubular; the pharynx, short, small, 1.3 mm long and wide; terminating in the middle of ix. The extrinsic radial muscles of the pharynx are sparse, present in vii, viii and ix. Salivary glands are spaced in vii to ix, the dorsals without obvious aggregated columns of ducts.

The crop commences with a short acaecate compartment in ix; compartments in x to xviii, each with a pair of caeca at the anterior and posterior levels, both pairs lobed distally, both pairs extending into the paramedian chambers; the caeca of the posterior pair increasing in length from xiii to xviii and distally digitate. The compartment in xix with a pair of distally lobed anterior caeca, and a pair of laterally lobed postcaeca commencing at the posterior level and continuing in the paramedian chamber to terminate in xxvi.

The crop connects terminally to the wide, compartmented intestine which connects to the end of the short tapering tubular rectum at xxiii/xxiv.

Reproductive Systems (Fig. 1, C, F)

Assessed as mature, male gravid.

Genital pores, the male posterior in xi b_5; the female at xii b_5/b_6.

Testes, saccular, intersomital, the most anterior at xiii/xiv, the most posterior at xxii/xxiii; total, 10 pairs. The posterior testes connecting laterally by a long vas efferens to the vas deferens which is lateral in the paramedian chamber, white, slightly tortuous, and extends anteriorly to xii/xiii. At this level, it narrows to continue as a thin-walled transparent tube which becomes highly convoluted to form a compact solid globular mass at xi/xii, the epididymis. The male duct continues again as a narrow transparent non-muscular duct which turns medially to enter the ventral aspect of the male atrium.

The male median region is formed on a posteriorly directed primary loop reflected at ganglion xii; the strongly muscular atrium in the posterior half of xi; the penis sheath occupying both limbs of the primary loop; the penis, very narrowly cylindrical.

The ovaries, saccular, situated at xii/xiii, continue as short narrow thin-walled oviducts which join to form the median region. There is no distinct atrial chamber.

The female median region formed on a posteriorly directed primary loop reflecting in the middle of xiii; the common oviduct, thick-walled, of greater diameter than the oviduct, slightly tortuous, occupies the greater part if not the whole of the initial recurrent limb of the loop, connects subterminally to the vagina which is caecate, essentially tubular, strongly muscular, and occupies the terminal procurrent limb of the loop. There is no vaginal duct.

The only indication of prostate glands are a few wide-spaced small patches on the surface of the atrium, which otherwise is almost entirely exposed. The albumin glands are a heavy investment of the entire length of the common oviduct.

Status of Hirudo catenulata Johansson 1918

This species of aquatic jawed sanguivore is known only in the original account which describes the external meristic morphology, the pattern, and the jaws. It is based on 6 specimens from the New Hebrides.

Progressively in studies on the Richardsonianidae, I have been able to demonstrate (1973) that topographically definable pattern has not only specific value, but also generic and familial values in genera characterized by the combination of external meristic morphology, the nature of the pharynx and associated structures, the organs and relationship of the organs on the anterior region of the male paired duct, and the nature of the median regions of the reproductive systems.

Although Johansson's account is incomplete, I have long been confident that the pattern he described excluded *catenulata* from the Richardsonianidae and the Ornithobdellidae, and was indicative of a third family in this Region.

Johansson does not describe the general form of *catenulata*. In pl. xii fig. 6, he shows relatively short, very wide 5-annulate somites. He gives the length (22.0 mm) and the maximum width (6.3 mm) for the largest specimen, but not the depth. The ratio of width to length is 1: 3.5. The ratio for *I. papuensis* is 1:3.3. In leeches of the usual form, elongate cylindrical to moderately depressed, the ratio is in the order of 1: 9 or 10, or contracted as 1: 5 or 6.

The pattern on 5-annulate somites is given as: a median row of regularly interrupted narrow elongate patches, each patch continuous across b_2, a_2, b_5, i.e. each patch having the same relationship to the annuli of the somite as the median elongate oblong patches in *papuensis*.

On either side of this median row, a continous narrow band, closer to the midline at the intersomital levels, curving laterally along the somite, and in this way incompletely enclosing the median patch. This is equivalent to the paired square patches and the lines connecting the outer corners of the patches in the somite in *papuensis*. Johansson's figure is indicative of small square patches on b_6 and b_1 together forming an elongate oblong.

The median row and the continuous paired bands correspond to and have the same relative total width as the median checkered band in *papuensis*.

Lateral to this, on each side: an inner interrupted band of elongate maculae; an outer interrupted band of longer maculae close to the margin; and between these, a longitudinal row of connected elongate large ovals.

The maculae of the inner band extend over b_2, a_2, b_5, and are separated over b_6 and b_1. The maculae of the outer band appear to be centred on b_6 and b_1, with some extending onto b_5 and b_2. The maculations of the inner band have the same relationship to the annuli in the somite as the inner row of elongate ovals in *papuensis*. *I. papuensis* does not show an equivalent to the outer paired band.

Between the paired bands of patches, there is a row of large elongate connected ovals, of the same size, location, and relationship to the annuli of the somite as the outer row of ovals in *papuensis*. Each oval extends over b_2, a_2, b_5, connecting to patches on b_1 and b_6, these patches fusing to similar patches on the contiguous annuli of the adjacent somites, and so having a catenulate appearance. The venter, maculate.

Johansson states that the could not detect somital sense organs. He describes the somital annulation as being similar to that of *Hirudo medicinalis* excepting xxiv, complete 5-annulate (i.e. ix to xxiv, 5-annulate, total 16); xxv, 4-annulate; xxvi, 3-annulate; xxvii, uniannulate; genital pores, xi and xii b_5/b_6. (The enumeration of the somites given here is revised on the basis of 27 preanal somites).

Jaws, lacking salivary gland papillae; 44 teeth in the dental row, the tallest at the median end.

The above indicates that *catenulata* has the general form, general somital annulation, and the essential features of the pattern in *papuensis;* that *catenulata* is recognizably a member of the Illebdellidae; and can be placed provisionally in the g. *Illebdella.*

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Contribution to the Study of Australian Nephtyidae (Polychaeta)

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Figures 1–13. Manuscript received 21st March, 1973, resubmitted 19th August, 1973.

ABSTRACT

Records of Australian Nephtyidae are reviewed. Two new species, *Inermonephtys palpata* and *Nephtys vikingensis*, are described. *Nephtys paradoxa* is newly recorded from Australian waters. A key to the seven Australian species is included.

INTRODUCTION

Six species of Australian nephtyids in two genera have been recorded so far (Fauchald, 1965; Knox and Cameron, 1971). One of these, *Nephtys mirocirrus* is referred to the older *N. gravieri*. Some records of *Aglaophamus dibranchis* and *A. macroura* refer to *A. verrilli*. Two new species in two genera are described here. *Nephtys picta* reported by Knox and Cameron is referred to one of these, *Nephtys vikingensis*, n. sp. This brings the total number of Australian nephtyids to seven species in three genera. The results are detailed in the systematic account below.

The material on which this study is based is deposited in the Allan Hancock Foundation, Los Angeles (AHF), The Australian Museum, Sydney (AMS), British Museum (Natural History), London (BMNH), National Museum of Victoria, Melbourne (NMV), and Queensland Museum, Brisbane (QM).

SYSTEMATIC ACCOUNT

Key to Nephtyidae from Australia

1. Interramal cirri recurved .... *Nephtys* . 4

— Interramal cirri involute 2

2. Proboscis with papillae; two pairs of antennae .... *Aglaophamus* . 3

— Proboscis without papillae; one pair of antennae .... *Inermonephtys palpata*, n. sp.

3. Neuropodial preacicular lobes entire; proboscis with fourteen rows of subterminal papillae .... *A. dibranchis*

— Neuropodial preacicular lobes incised; proboscis with twenty-two rows of subterminal papillae .... *A. verrilli*

4. Interramal cirri with lateral foliaceous lobes; postacicular setae almost smooth *N. paradoxa*

— Interramal cirri without lateral foliaceous lobes; some postacicular setae coarsely denticulated 5

5. Prostomium with triangular preantennal lobe; interramal cirri slender and long *N. vikingensis*, n. sp.

— Prostomium without preantennal lobe; interramal cirri thick and short 6

6. Interramal cirri from setiger 3; acicular lobes of median parapodia incised *N. gravieri*

— Interramal cirri from setiger 4; acicular lobes of median parapodia entire *N. australiensis*

Aglaophamus Kinberg, 1866

Aglaophamus dibranchis (Grube, 1878)

Nephthys dibranchis.—Augener, 1922: 17–20, fig. 5; 1927: 116–118.—Fauvel, 1932: 117 (in part).

Nephtys (Aglaophamus) dibranchis.—Day, 1967: 341, figs 15.I.a-h.

Remarks.—No specimens are available.

Distribution.—New Guinea, Australia, New Zealand, Indian Ocean.

Aglaophamus verrilli (McIntosh, 1885)

Nephthys verrilli McIntosh, 1885: 163–164, pl. 36, figs 6, 7, pl. 32A, fig. 8.

?*Nephthys macrura*[sic].—Benham, 1915: 203–205, fig. 57. (Not *Nephthys macroura* *Schmarda*, 1861).

Nephtys dibranchis.—Fauvel, 1932: 117 (in part).—Monro, 1936: 139.—Rullier, 1965: 182–183.

Aglaophamus dicirris Hartman, 1950: 122–124, pl. 18, figs 1–8.

Aglaophamus verrilli.—Knox, 1960: 115.

Material examined.—Queensland (QM G3920–3923; as *N. dibranchis* by Rullier, 1965). Bass Strait, 40 miles east-north-east of Babel Island, approx. 39° 04′S, 148° 43′E, 1200 fms, F.I.S. *Endeavour.*—anterior fragment (AMS E5113; as *N. macrura* by Benham, 1915).

Remarks.—*Aglaophamus verrilli* is closely related to *A. dibranchis*. The two species differ in that the former has twenty-two rows of subterminal proboscidial papillae, of which none is distinctly larger and middorsal or -ventral, while the latter has fourteen rows and a long middorsal papilla. The interramal cirrus of *A. dibranchis* starts on setiger 4 (Day, 1967: 341), while its origin varies from setiger 5–8 in *A. verrilli* (Pettibone, 1963: 190). Both preacicular lobes of *A. verrilli* are short; the neuropodial one is incised. The corresponding lobes of *A. dibranchis* are also small, but both are complete and of auricular shape. The postacicular lobes of the former are rounded while those of the latter are auricular.

The specimens reported by Rullier (1965) as *N. dibranchis* were examined and are referred to *A. verrilli*. The everted probosces showed in all cases twenty-two rows of subterminal papillae as mentioned by Rullier. The interramal cirri were first present from setiger 7, rarely 8, never 5 as stated by Rullier. The parapodia were characteristic for *A. verrilli*.

Benham (1915) reported *Nephthys macrura* from Bass Strait. He mentioned that his specimen differed from the original description with respects to its proboscidial papillae, head proportions and notopodial lobes. The specimen was examined; it does not represent *A. macroura* as redescribed by Hartman (1967: 74–76, pl. 23). The specimen resembles most closely *A. verrilli*, to which it is referred as a questionable record. The parapodia (fig. 1) differ from those of the Queensland specimens, in that the erect neuropodial lobes and interramal cirri are shorter and thicker in the former. No lyrate setae could be found, but they may be broken off. The interramal cirri are present from setiger 8, not 9 as stated by Benham.

Distribution.—New Zealand, Australia, India, North America to Panama.

Inermonephtys Fauchald, 1968

Inermonephtys palpata, new species

(Figs 2–6)

Material examined.—Queensland, Queens Beach, Port Denison, Bowen, approx. 20° 03′S, 148°15′E, sandflat, 27 July, 1925, E. H. Rainford, collector—holotype (AMS W1710).

Description.—The description is based on a single, complete specimen. It measures 150 mm by 4.5 mm without and 6 mm with parapodia and consists of 215 setigers.

The preserved specimen is pale with orange colour spots. This pigmentation lightly covers the prostomium, runs in two stripes from the nuchal organs to the second setigerous segment, then continues as a longitudinal middorsal band through three segments (fig. 2). Lateral markings are also prominent on the 3rd and 4th setigers. On the ventrum pigmentation occurs around the mouth and bases of the neuropodia in the anterior thirty segments.

The prostomium is subrectangular, slightly longer than wide, with rounded frontal corners. Frontal antennae are absent as typical of the genus. The bifid, ventrally attached lateral antennae (fig. 3) consist of a large palp-like organ projecting beyond the prostomium and carrying a small digitate process. The nuchal organs are present as everted digitiform processes slightly below the postectal margins of the prostomium. The left side bears three cirriform processes, the right side has two and the place of attachment for the third is visible. No eyespots can be discerned.

The proboscis was examined by dissection; it lacks papillae. The jaws are spindle-shaped.

The first segment is directed forward at either side of the prostomium; it is continuous across the middorsum. The notopodial acicular and preacicular lobes are little developed, while the postacicular ones are rounded and inflated, padlike. The notopodial cirri are well developed with a bulbous base and slender tip. All three lobes of the first neuropodium are rudimentary. The neuropodial cirri are of the same length as later ones. They have a bulbous base with irregularly shaped tips. At the base of the neuropodium is a well developed lamella. These lamellae are rudimentary in the following anterior segments but come to be larger again in median and posterior segments.

In well-developed segments (fig. 4) the two rami are widely separated. The notopodial acicular lobe has a bulbous base ending in a digitiform lobe. The aciculum projects at the junction at the superior side. The preacicular lobe is slender, with a rounded tip; it increases in size towards median segments where it reaches the size of the postacicular lobe. The postacicular lobes have rounded tips and are inflated in the first thirty segments. Thereafter they are flatter and more slender. The notopodial cirrus is digitate and slender, its length exceeding the notopodial lobes in median segments.

Opposite

Aglaophamus ?verrilli (specimen E5113): Figure 1, twenty-fifth parapodium in anterior view, setae omitted, X 50. *Inermonephtys palpata*, n. sp. (holotype W1710): Figure 2, anterior end through third segment, in dorsal view, X 12.5. Figure 3, anterior end through third segment, in ventral view, X 12.5. Figure 4, twenty-fifth parapodium in anterior view, setae omitted, X 25. Figure 5, subdistal part of preacicular, barred seta in lateral view, X 250. Figure 6, postacicular lyrate seta, X 250.

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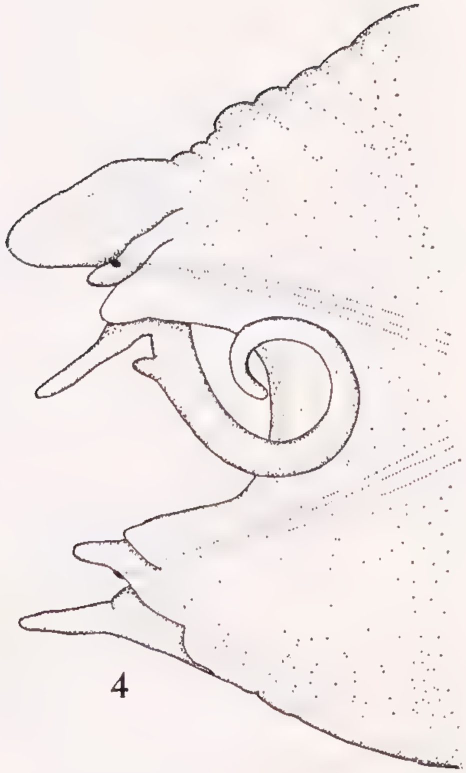

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2

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5

6

The neuropodial acicular lobe also has a bulbous base and a digitate lobe after the projection of the aciculum at the inferior side. The preacicular lobe is shortest in the anterior segments. Its length increases towards median segments to surpass the acicular lobe. The postacicular lobe is short and rounded throughout. The neuropodial cirrus is irregularly formed in the first fifteen segments. Thereafter they have broad bulbous bases with slender tips. Due to their posterior position they can be mistaken as postacicular lobes.

The interramal cirrus starts on setiger 2 and is involuted by setiger 5. It is slender and becomes long, filling the interramal space; it decreases slightly towards the end of the body and is absent from the last six segments. An accessory cirrus is present after the first ten segments.

The setae of the anteriormost segments are strongly geniculate and long, thereafter they decrease in length. Setae emerge as an open spiral around the acicular lobe, with the opening at the preacicular lobe, thus giving the impression of a divided preacicular fascicle. The preacicular fascicle has short, stout, slightly geniculate setae with rows of small denticles towards the distal half. They grade from clear to barred setae, showing various degrees of bars. Even the strongly barred setae retain their denticles (fig. 5). Two acicula are present in each ramus. They project at a common point and are capped by a conspicuous reddish plaque.

The postacicular fascicles consist of longer, straighter setae also with closely-set denticles along the whole length as in the preacicular ones. A few lyrate setae (fig. 6) are also present in noto- and neuropodial postacicular fascicles.

I. palpata differs from the two known species of *Inermonephtys*, *I. inermis* (Ehlers, 1887) from Florida, and *I. gallardi* Fauchald, 1968 from Vietnam, in that the first has bifid, palp-like lateral antennae, three eversible nuchal processes, and denticulated barred preacicular setae. The parapodia of *I. palpata* resemble those of *I. gallardi* in having digitiform lobes on the acicular lobes and divided preacicular fascicles; they differ in the shape of the post-acicular lobes.

Nephtys Cuvier, 1817

Nephtys australiensis Fauchald, 1965

(Fig. 7)

Nephthys gravieri.—Augener, 1927: 116.—Rullier, 1965: 182.

Nephtys australiensis Fauchald, 1965: 334–335, figs 1, 2.

Material examined.—South Australia, Port Vincent, Yorke Peninsula, sand—holotype (AMS W3783). Numerous specimens from eastern Australia and one station from Western Australia, Leschenault Estuary, Bunbury (AMS W4335).

Other material examined.—Queensland (QM G3635, G3637; as *N. gravieri* by Rullier, 1965).

Remarks.—This species is the commonest Australian nephtyid. It occurs in sandy, muddy estuaries and is often found with the nereid, *Australonereis ehlersi* Hartman, 1954.

Most well-preserved specimens display a typical pigmentation pattern which covers the prostomium and anterior setigers (fig. 7). The teeth of the coarsely denticulated postacicular setae are not in a single row at the cutting edge as described by Fauchald (1965) but in transverse rows.

Augener's (1927: 116) record is referred to this species as suggested by Fauchald (1965) since the neotopodial cirri are almost egg-shaped in outline.

The specimens reported by Rullier (1965) as *N. gravieri* were examined and are referred to *N. australiensis*. These two species have similar parapodia and setae. They differ in that *N. australiensis* has broad, foliaceous notopodial cirri and complete conical lobes whereas *N. gravieri* has digitiform notopodial cirri and incised acicular lobes in median segments.

Distribution.—Queensland, New South Wales, Victoria, South Australia and Western Australia.

Nephtys gravieri Augener, 1913

Nephthys gravieri Augener, 1913: 123–125, pl. 2, fig. 5, text-figs 6a-c.—Fauvel, 1932: 118; 1953: 226, figs 114a-c (in part).

Nephtys mirocirris Fauchald, 1965: 335–336, figs 3, 4.

Material examined.—South Australia, Clinton, Yorke Peninsula, sand—holotype of *N. mirocirris* (AMS W3782).

Remarks.—The type specimen of *N. gravieri* comes from Fremantle, Western Australia. Augener considered the coarsely denticulated postacicular setae as characteristic for the species which he otherwise believed to be close to *N. palatii* Gravier. He did not mention whether the proboscis had a middorsal papilla, whether its proximal surface was smooth or prickly, and at which setiger the interramal cirri originated.

Fauvel (1932) reported *N. gravieri* from the Bay of Bengal, India. His description agreed with that of Augener. Fauvel (1953) repeated this description and gave two figures. The figure of prostomium and anterior segments (fig. 114a) is a copy of Augener (pl. 2, fig. 5) while the parapodium (fig. 114b) does not agree with *N. gravieri* since it has an involute interramal cirrus characteristic of *Aglaophamus*.

Fauchald (1965) described *N. mirocirris* agreeing in most respects with *N. gravieri* Augener, 1913. The two differ in that the first has a deep incision in the notopodial aicular lobe and prickles on the proximal surface of the proboscis; Fauchald presumed that both features are lacking in *N. gravieri*. Augener (1913: 124) did not mention that the notopodial acicular lobe is incised, but his text-fig. 6c clearly shows it as being so. There are no barred preacicular setae in this species contrary to the description of Fauchald (1956: 336).

The two species are identical, with *N. mirocirris* the junior synonym. The account of Augener can be emended to include: the proximal surface of the proboscis is covered with minute prickles and it lacks a subterminal median papilla. The interramal cirri are first present from setiger 3.

Distribution.—Fremantle, Western Australia and Yorke Peninsula, South Australia; Bay of Bengal, India.

Nephtys longipes Stimpson, 1855

Nephthys longipes Stimpson, 1855: 7; 1856: 392.

Remarks.—This species was described from Botany Bay, Australia. It is considered as indeterminable on the basis of its insufficient description.

Nephtys paradoxa Malm, 1874

Nephtys paradoxa.—Fauchald, 1963: 13–15, figs 1A, 2B, 3C.

Material examined.—New South Wales, 33 miles from Green Cape. approx. 37° 16′S, 150° 10′E, 470 fms., 2 October, 1912, F.I.S.

Endeavour.—1 specimen (AMS W5247).

Remarks.—The anterior fragment measures 35 mm long by 8 mm wide for thirty-seven segments. The proboscis is fully everted and displays twenty-two rows each with five to six papillae. The proximal surface of the proboscis is smooth. Interramal cirri are present from setiger 12, become foliaceous from setigers 14 to 18 and are fully developed from setigers 20 to 34. From setiger 35 they are abruptly small again.

Distribution.—*N. paradoxa* is a deep-water species widely distributed in the northern Atlantic Ocean. It has been reported from the Sea of Japan and the Sea of Okhotsk (Ushakov, 1955: 216) and subantarctic areas off Chile (Hartman, 1967: 81–82). This is a new record from Australian waters.

Nephtys vikingensis, new species

(Figs 8–13)

Nephtys picta.—Knox and Cameron, 1971: 28, figs. 15–16.

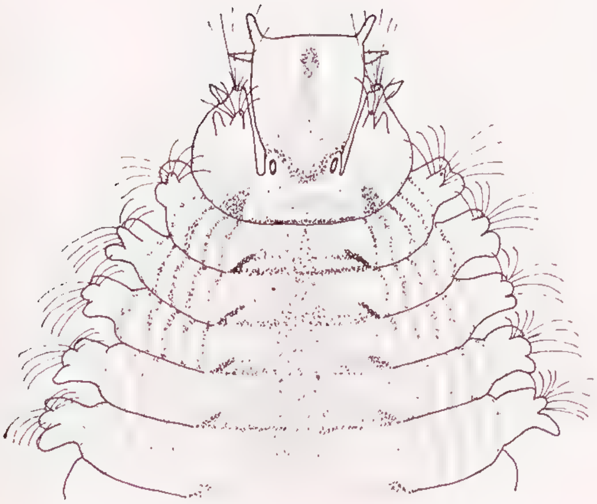
Material examined.—New South Wales, Bateman's Bay, approx. 35° 62′S, 150° 11′E, sandflat, December 1960, I. Bennett, collector—HOLOTYPE (AMS W5251) and 4 PARATYPES (AMS 5253–4; AHF Poly 1002; BMNH ZB.1973.6). Wallis Lake, approx. 32° 15′S, 152° 30′E, Prof. O'Gower and students, collectors—PARATYPE (AMS W5252). Queensland, Moreton Bay, J. D. Ogilby, collector—1 specimen (AMS W5401).

Other material examined.—Victoria, Anglesea, Port Philip Survey, 1957–63—1 specimen (NMV G1789; as *N. picta* by Knox and Cameron, 1971).

Description.—The holotype is a complete specimen. It consists of 143 setigers and measures 82 mm by 3 mm without and 4 mm with parapodia at anterior segments. Three paratypes are complete (AMS W5252, AHF Poly 1002, BMNH ZB.1973.6), consisting of 123, 139 and 143 setigers, with lengths of 56, 72 and 88 mm respectively. Two paratypes (AMS W5253–4) consist of anterior fragments of 109 and 83 setigers, with lengths of 103 and 40 mm respectively.

Opposite

Nephtys australiensis (specimen W4980): Figure 7, anterior end through sixth segment, in dorsal view, X 20. *Nephtys vikingensis*, n. sp. (holotype W 5251, except where otherwise indicated): Figure 8, anterior end with everted proboscis through third segment, in dorsal view, X 12.5. Figure 9, thirtieth parapodium in anterior view, setae omitted, X 12.5. Figure 10, thirtieth parapodium of paratype W5253 in anterior view, setae omitted, X 25. Figure 11, part of preacicular barred seta in lateral view, X 400. Figure 12, subdistal part of strongly denticulated postacicularseta, X 200. Figure 13, enlarged part of same seta, X 600.



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The most striking feature of this species is the cephalic end (fig. 8). The prostomium is oval, slightly longer than wide. A thin, preantennal lobe, also found in other species of *Nephtys*, has been developed as a triangular translucent lobe, marked by an intricate pattern of slightly thicker tissue. The frontal antennae are slender and arise at the sides of the base of the preantennal lobe. The lobe with the frontal antennae give the impression of a Viking helmet, hence the specific name.

The lateral antennae are longer than the frontal; each has a bulbous base and slender tip. The everted nuchal organs appear as small papillae at the postectal margins of the prostomium.

The proboscis of the holotype is not completely everted. The description is that of paratype W5254. The proboscis has twenty bifid terminal papillae, ten of each side set apart by a smaller, single middorsal and midventral one. The subterminal papillae are in twenty-two irregular, longitudinal rows. Each row has five to seven papillae decreasing in size proximally. None of the papillae are distinctly middorsal or midventral. The proximal surface of the proboscis is covered with minute prickles.

The first setigerous segment is greatly prolonged. It is as long as the next two segments combined. The median part of the first setiger is covered by a brown pigment in some specimens. The pigment is continued on the following segments, getting lighter prosteriorly and fading out by the tenth segment.

The first parapodia are directed forwards to lie at the sides of the prostomium. The notopodium has a rounded acicular lobe; the other lobes are little developed. The notopodial cirrus is short and digitate. The notopodial fascicle bears barred setae and geniculate spinigers.

The first neuropodium has a pointed acicular lobe. It bears a digitate cirrus, longer and more slender than the notopodial cirrus. The setae consist of straight and slightly geniculate spinigers. They are directed forward, reaching to the base of the frontal antennae.

The notopodial acicular lobes of fully developed parapodia (fig. 9) are rounded, with the aciculum projecting at the superior side. The notopodial postacicular lobe is rounded, and of the same length as the acicular lobe. The preacicular lobe is short and rounded. The notopodial cirrus is digitate, broader at its base. The neuropodial acicular, post- and preacicular lobes are rounded, the preacicular being the smallest, and the postacicular the largest. The neuropodial cirrus is digitate.

The interramal cirrus is first present from setiger 3 and is recurved from setiger 4. It has a pronounced knob close to the notopodial cirrus, and is digitate and recurved. The interramal cirrus of the holotype and other small but mature specimens never fills the interramal space while in larger specimens (fig. 10) it is long and slender and fills the entire space. The cirrus becomes smaller in posterior segments, is not recurved and is completely absent from the last eight to ten segments. The interramal area and cirri are distinctly ciliated.

The setae are long and flowing, in most cases as long as the body is wide. They consist of three kinds. The preacicular fascicles contain short, barred setae (fig. 11) and less numerous long, finely denticulated setae. The postacicular fascicle contains a few of the latter but mainly geniculate setae (figs 12, 13) with transverse rows of coarser denticles. The setae end in long, slender tips. Most of the strongly denticulated geniculate setae are light yellow, while some are much darker and under high magnification are seen to be punctate. There seems to be no relationship between the age of setae and being punctate.

N. vikingensis differs from all other species of *Nephtys* in having a large preantennal lobe. It is related to *N. gravieri* and *N. serratus* in having the interramal cirrus from the third setiger and the absence of a middorsal subterminal papilla on the proboscis. It is related to *N. longosetosa* with respect to the position of the interramal cirrus, the long setae and presence of a thin preantennal lobe. *N. vikingensis* differs from all three species in having a greatly prolonged first segment.

The specimen reported as *N. picta* by Knox and Cameron (1971) was examined; it is unquestionably *N. vikingensis*.

Distribution.—*N. vikingensis* has been collected in New South Wales, Victoria and Queensland; it occurs in clean sand. In some stations from Wallis Lake it was found together with *N. australiensis*.

ACKNOWLEDGMENTS

I wish to express my thanks to the Trustees of The Australian Museum for the chance to study the collection and thank Mrs Carden Wallace (QM) and Dr Brian Smith (NMV) for loan of material. I sincerely thank Drs Olga Hartman and Kristian Fauchald for their encouragement and criticism.

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THE PSOCOPTERA (INSECTA) OF NORFOLK ISLAND

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Figures 1–67. Manuscript received, 14th September, 1973.

SUMMARY

Fourteen species of Psocoptera are listed from Norfolk Island, of which eleven are described as new. The material recorded was collected widely over the island between 1967 and 1972 as part of a study of the psocopteran fauna of the Melanesian Arc.

INTRODUCTION

Apart from brief mention by Hawkins (1943), who gives family or generic determinations only for a few specimens, nothing has been published on the Psocoptera of Norfolk Island. This paper deals with material collected at various times between 1967 and 1972, the work being part of a study of the psocopteran fauna of the islands of the Melanesian arc. Fourteen species are now known from the island, of which eleven are here described as new. Material was collected mainly by beating and it seems likely that a high proportion of the species obtainable by this method have been taken.

Zoogeographical discussion has been omitted from this paper as we have extensive material, which has not yet been critically examined, from relevant areas, such as Fiji, New Guinea, and New Caledonia, and any comments made at this stage of the study would be premature. Zoogeographical matters will be discussed when our field programme has taken in other areas, such as New Britain, and when the material from the other areas has been dealt with systematically.

Species of which many specimens have been taken are fairly widely distributed over the island; the island is small and was originally covered with fairly uniform vegetation. Habitat preferences of Psocoptera have not been studied on Norfolk Island.

LIST OF SPECIES OF PSOCOPTERA FROM NORFOLK ISLAND

Lepidopsocidae

Pteroxanium ralstonae sp. n.
Pteroxanium evansi sp. n.
Pteroxanium insularum sp. n.
Lepolepis graemei sp. n.

Caeciliidae

Caecilius insulatus sp. n.
Caecilius pacificus sp. n.

Ectopsocidae

Ectopsocus briggsi McLachlan
Ectopsocus insularis sp. n.
Ectopsocus inornatus sp. n.

Peripsocidae

Peripsocus milleri (Tillyard)
Peripsocus norfolkensis sp. n.

Pseudocaeciliidae

Heterocaecilius variabilis sp. n.

Philotarsidae

Haplophallus emmus sp. n.

Psocidae

Blaste lignicola (Enderlein)

SYSTEMATIC ACCOUNT

LEPIDOPSOCIDAE

Pteroxanium ralstonae sp. n.

MALE

Coloration (in alcohol).—Median epicranial suture very dark brown; anterior arms paler. Vertex dark brown, fading anteriorly to the pale brown frons. Postclypeus dark posteriorly, pale in anterior half, the change in colour occurring over a narrow transverse zone. Anteclypeus pale. Labrum very dark brown. Genae dark brown. Antennae with about ten basal segments brown, becoming darker distally. Eyes black. A small black spot occurs in position usually occupied

by median ocellus. Maxillary palp brown, with dark brown distal segment. Pro- and mesothoracic nota shining, dark brown. Tibiae dark brown with three pale bands, that nearest the femur being narrowest, the middle and distal bands being wider and of equal width to the dark bands separating them. Basal tarsal segments dark brown basally, fading distally; middle and distal segments pale brown. Fore wings (fig. 1) very dark brown, pale near apex. Veins darker than membrane. Hind wing a small translucent flap. Abdomen colourless except for the sclerotized second tergite and the dark brown terminal structures; these are conspicuously darker than the rest of the abdomen. Abdominal scales dark, easily lost; in life these give a sheen to the abdomen.

Morphology.—Length of body: 2.8 mm. Median epicranial suture and its anterior arms distinct. Vertex fairly sharp, bearing strongly developed, dark brown setae; other parts of epicranial plates and frons with short, fine setae. Genae strongly pubescent ventrally. Antennae with at least forty segments. Eyes large, not quite reaching level of vertex. Ocelli absent. Lacinia (fig. 3). Prothoracic notum with a covering of very stout setae; mesonotum clothed with scales. Measurements of hind leg: F: 0.700 mm; T: 0.952 mm; t_1: 0.406 mm; t_2: 0.084 mm; t_3: 0.084 mm; rt: 4.8:1:1. Hind tibia with two large apical spines and one small one. Basal tarsal segment with three spines ventrally in addition to two larger and one small spine apically and one large, laterally placed spine preapically. Claw with preapical tooth and a few minute denticles basad of tooth. Fore wing length: 0.77 mm; fore wing width: 0.49 mm. Fore wing (fig. 1) reduced, elytriform, bearing spaced macrochaetae (represented by alveoli in figure) between which are sited numerous scales and scale-like setae. Venation hardly discernible, variable, but most frequently as in figure. Wings easily detached. Hind wing a minute, transparent, tapering, slightly upcurved rudiment. Abdomen membranous except for strongly sclerotized ninth tergite and terminal structures. Paraprocts with three setae arising from "rosette" bases in addition to other scattered setae. Hypandrium a large, broad plate, well sclerotized except for a small triangular membranous area at the middle of the hind margin, hind margin thus appearing notched. Phallosome (fig. 2) (distorted in preparation).

FEMALE

Coloration (in alcohol).—As male.

Morphology.—Length of body: 2.6 mm. General morphology as male. Measurements of hind legs and wings as male. Gonapophyses (fig. 4). Sclerification of spermapore plate (fig. 5).

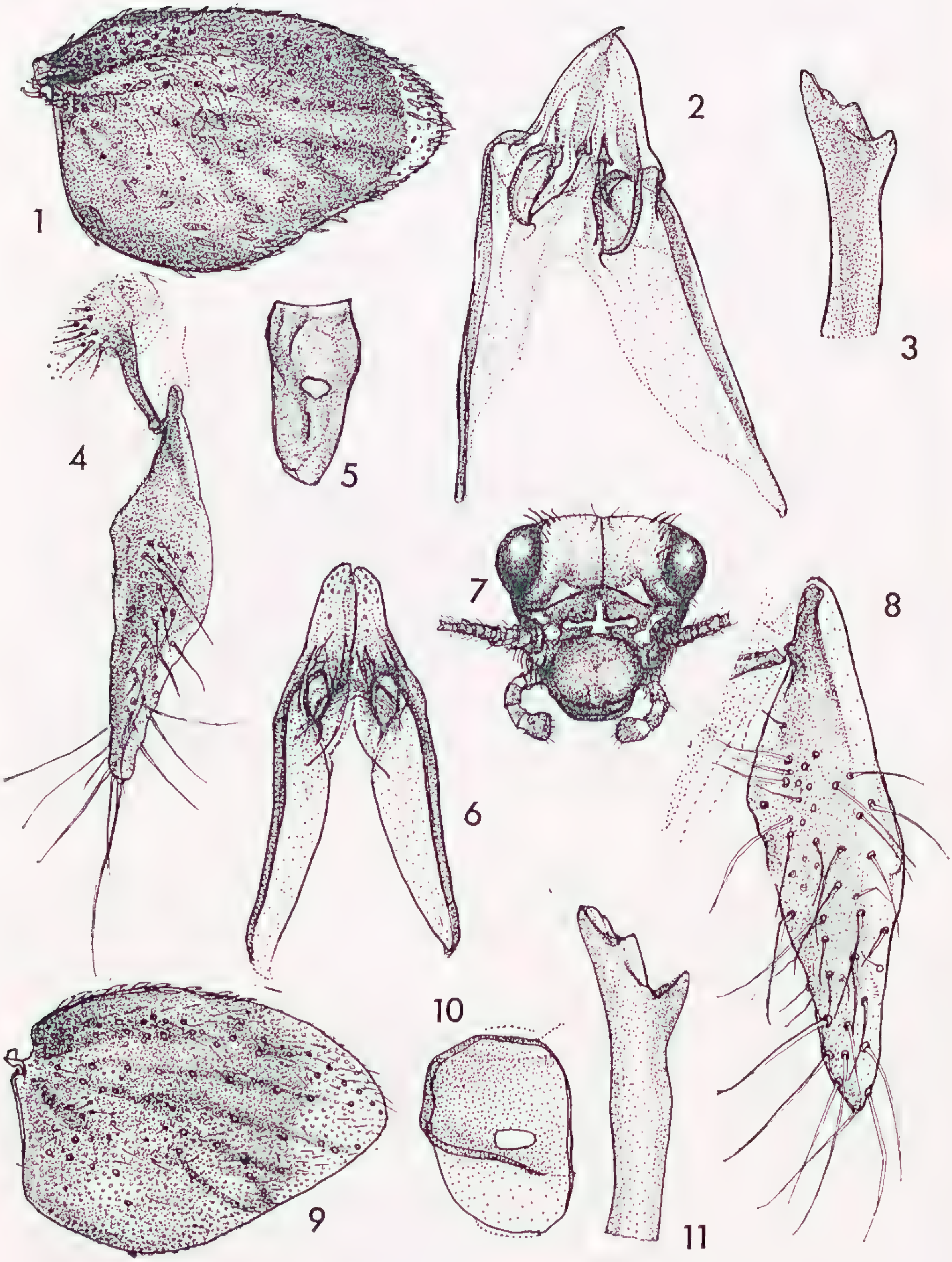
MATERIAL EXAMINED

Norfolk Island: 3 ♂ (including holotype), 5 ♀ (including allotype), Collin's Head, 30.viii.1971. (C. N. Smithers and I. W. B. Thornton.) Holotype, allotype, and paratypes in Australian Museum.

DISCUSSION

This species can be distinguished from both *Pteroxanium kelloggi* (Ribaga) and *P. funebris* Badonnel by the lack of a facial pattern and by differences of wing form and coloration. Both sexes are known in *P. funebris* and *P. ralstonae; P. kelloggi* is parthenogenetic.

This species is named in honour of the late Mrs P. Ralston, whose efforts in the cause of the conservation of Norfolk Island have been untiring and an inspiration to others.



Figs 1–5. *Pteroxanium ralstonae* sp. n. 1, ♂ fore wing; 2, ♂ phallosome; 3, ♂ lacinia; 4, ♀ gonapophyses; 5, ♀ sclerites of 9th sternite. Figs 6–11. *Pteroxanium evansi* sp. n. 6, ♂ phallosome; 7, ♂ head; 8, ♀ gonapophyses; 9, ♂ fore wing; 10, ♀ sclerites of 9th sternite; 11, ♂ lacinia.

Pteroxanium evansi sp. n.

MALE

Coloration (in alcohol).—Head varies in depth of colour, but characteristic pattern is apparent. In well-pigmented specimens (fig. 7) the vertex is pale brown with dark median epicranial suture. Front of head with characteristic pattern, postclypeus being similar in colour to epicranial plates. Genae dark brown with slightly paler stripe running from below compound eye towards antenna base. Antennae dark brown. Eyes black. Maxillary palp dark brown. Femora brown; tibiae dark brown except for a pale band at each end and a pale narrow band in the middle. Tarsi pale brown except darker base of basal segment. Fore wing (fig. 9) dark with pale apical area. Abdomen pale with dark terminal structures.

Morphology.—Length of body: 2.2 mm. Median epicranial suture and its anterior arms very distinct. Setae of head as in *P. ralstonae*. Eyes fairly large, not reaching level of vertex. Median ocellus rudiment present; lateral ocelli absent. Lacinia (fig. 11). Measurements of hind leg: F: 0.644 mm; T: 0.896 mm; t_1: 0.392 mm; t_2: 0.098 mm; t_3: 0.098 mm; rt: 4:1:1. Hind tibia with two large apical spines; basal tarsal segment with three or four spines along its ventral side and one large and one small spine apically. Fore wing length: 0.65 mm; fore wing width: 0.40 mm. Fore wing narrow distally, elytriform. Wing clothed with scales and scattered, strongly developed setae, all easily detached. Hind wing a vestige. Epiproct simple, semicircular, with a few strong, scattered setae. Paraproct with three setae arising from "rosette" bases in addition to other scattered setae, one of which is longer than width of paraproct. Hypandrium simple, well sclerotized. Phallosome (fig. 6).

FEMALE

Coloration (in alcohol).—As male.

Morphology.—Length of body: 2.4 mm. General morphology as male. Sclerification of spermapore plate (fig. 10). Gonapophyses (fig. 8).

MATERIAL EXAMINED

Norfolk Island: 4 ♂ (including holotype), 9 ♀ (including allotype), Bumbora, 26.viii.1971; 2 ♂, 5 ♀, Rocky Point Reserve, 28.viii.1971; 6 ♂, 6 ♀, Collin's Head, 30.viii.1971; 11 ♂, 6 ♀, Selwyn Reserve, 30.viii.1971; 5 ♂, 18 ♀, Point Blackbourne, 25.viii.1971, 2 ♀, Stockyard Creek, 25.viii.1971; 1 ♀, Mount Pitt, 29.viii.1971 (all collected by C. N. Smithers and I. W. B. Thornton); 2 ♂, 3 ♀, 21–29.x.1967; 2 ♂, 3 ♀, Rocky Point Reserve, 23.xii.1968 (C. N. Smithers).

Holotype, allotype, and paratypes in Australian Museum; paratypes in Australian National Insect Collection, British Museum and Bernice P. Bishop Museum.

DISCUSSION

The facial pattern of this species is distinctive.

The species is named in honour of Mr Owen Evans in appreciation of the help he has given to scientists and others interested in the conservation of Norfolk Island.

Pteroxanium insularum sp. n.

MALE

Coloration (in alcohol).—Depth of colour pattern very variable, but characteristic pattern apparent. In well-pigmented specimens (fig. 12) vertex creamy yellow with brown median epicranial suture. Front of head with characteristic pattern; postclypeus a little darker than vertex, antero-lateral edge bordered internally with brown. Labrum dark brown. Genae dark brown. Scape, pedicel and basal flagellar segments pale brown, flagellum darker distally. Eyes black. Maxillary palp pale brown, distal segment a little darker than others. Prothorax and mesothorax creamy yellow with a dorso-lateral dark-brown stripe; metathorax without stripe. Legs creamy yellow, banded with brown. Prothoracic and mesothoracic tibiae with two bands and basal half of basal tarsal segment brown; metathoracic legs similar but an additional dorsal brown mark on distal half of femur. Fore wing (fig. 13) marked in shades of brown; the extent of the colour varies but there are always pale areas in addition to that near the wing apex. Hind wings small colourless lobes. Abdomen pale creamy yellow; terminal structures brown.

Morphology.—Length of body: 2.5 mm. Epicranial suture very distinct. Setae of head as in *P. ralstonae*. Eyes large, almost reaching level of vertex. Ocelli absent. Measurements of hind leg: F: 0.756 mm; T: 1.120 mm; t_1: 0.476 mm; t_2: 0.098 mm; t_3: 0.098 mm; rt: 4.8:1:1. Hind tibia with two large and one small apical spine, basal tarsal segment with four spines along inner side and two large apical spines. Fore wing length: 0.92 mm; fore wing width: 0.50 mm. Fore wing (fig. 13) narrowing distally, elytriform, some veins hardly visible. Wing clothed with scales and scattered, strongly developed setae, all easily detached. Hind wing a small tapering lobe. Epiproct simple, semi-circular, with a few strong, scattered, easily detached setae, and a row of small, fine, marginal setae. Paraproct lacks setae with "rosette" bases but a few setae present. Hypandrium simple, well sclerotized. Phallosome (fig. 14).

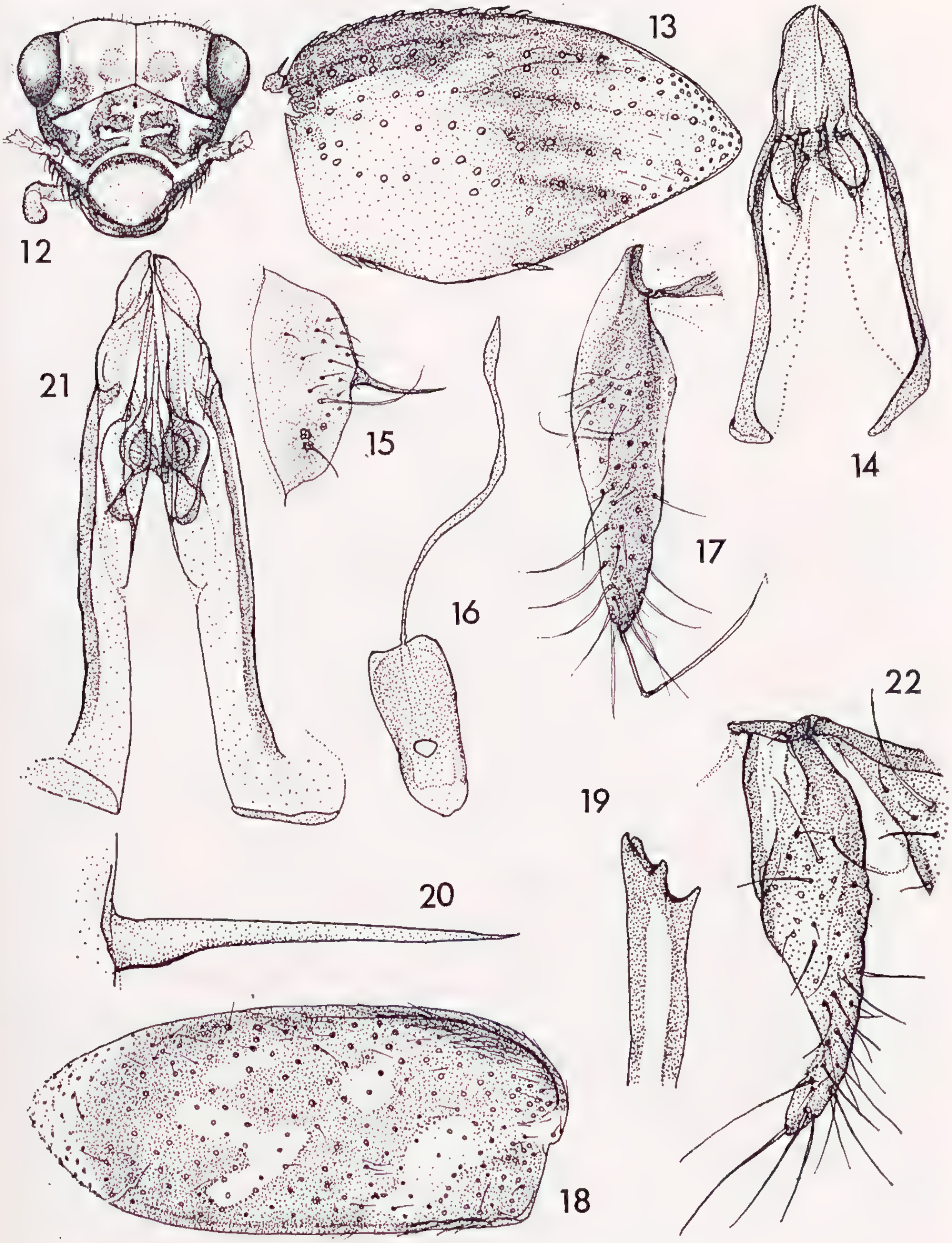
FEMALE

Coloration (in alcohol).—As male.

Morphology.—Length of body: 2.5 mm. General morphology as male. Paraproct (fig. 15). Sclerification of spermapore plate (fig. 16). Gonapophyses (fig. 17).

MATERIAL EXAMINED

Norfolk Island: 3 ♂ (including holotype), 8 ♀ (including allotype), 2 nymphs, Point Ross, 27.xi.1968; 1 ♀, Mount Pitt, 23.iii.1969; 4 ♂, 12 ♀, Captain Cook Monument, 22.xi.1968; 17 ♂, 17 ♀, 21–29.x.1967; 5 ♂, 4 ♀, Collin's Head, 24.iii.1969; 1 ♀, Jonneniggabunnit, 24.iii.1969 (C. N. Smithers); 8 ♂, 13 ♀, Melanesian Mission, 20.xi.1968; 11 ♂, 13 ♀, Mount Pitt, 19–21.xi.1968; 3 ♂, 6 ♀, Burnt Pine, 21.xi.1968; 3 ♂, 6 ♀, Palm Glen, 22.xi.1968 (A. S. Smithers); 2 ♀, Mount Pitt, 19.xi.1968 (G. F. Smithers); 11 ♂, 8 ♀, Mount Pitt, 28–29.viii.1971; 2 ♂, 3 ♀, Collin's Head, 30.viii.1971; 1 ♂, 1 ♀, 1 nymph, in garden, Aunt Em's Guesthouse, 3.ix.1971; 3 ♂, 7 ♀, 1 nymph, Mount Pitt-Mount Bates path, 2.ix.1971; 11 ♂, 13 ♀, Selwyn Pine Rd, 31.viii.1971; 7 ♂, 8 ♀, Point Ross, 31.viii.1971; 6 ♂, 12 ♀, Point Blackbourne, 25.viii.1971; 1 ♂, 2 ♀, Mount Bates Rd, 29.viii.1971; 1 ♂, 5 ♀, on Cypress trees, Mission Rd, 28.viii.1971; 4 ♀, Cascade-Red Rd, 28.viii.1971; 2 ♂, 6 ♀, Stockyard Creek, 25.viii.1971; 10 ♂, 15 ♀, Captain Cook Monument, 31.viii.1971 (C. N. Smithers and I. W. B. Thornton); 1 nymph, Mount Pitt slopes, 15.iv.1972 (A. L. Dyce, H. A. Standfast, and P. Ferrar).



Figs 12–17. *Pteroxanium insularum* sp. n. 12, ♂ head; 13, ♂ fore wing; 14, ♂ phallosome; 15, ♀ paraproct; 16, ♀ sclerite of 9th sternite; 17, ♀ gonapophyses. Figs 18–22. *Lepolepis graemei* sp. n. 18, ♂ fore wing; 19, ♂ lacinia; 20, ♂ paraproct spine; 21, ♂ phallosome; 22, ♀ gonapophyses.

Phillip Island: 1 ♀, 26.xi.1968 (C. N. Smithers).

Holotype, allotype, and paratypes in Australian Museum; paratypes in Australian National Insect Collection, British Museum and Bernice P. Bishop Museum.

DISCUSSION

The facial pattern of this species is distinctive; it is a larger species than *P. evansi.*

Lepolepis graemei sp. n.

MALE

Coloration (in alcohol).—Head and body brown, the postclypeus and labrum a little darker than the rest of the head. Genae dark brown. Antennae brown. Eyes black. Maxillary palp pale brown, a little darker in distal half of apical segment. Dorsum of meso- and metathorax brown. Legs brown. Fore wings (fig. 18) brown with hyaline areas; apical hyaline area always present, other areas vary considerably in extent, in some cases being more extensive than pigmented area. Abdomen brown ventrally; terminal structures brown; dorsally, median part of the seventh tergite and whole of eighth and ninth tergites of the abdomen thus brown; remaining tergites colourless (the dark areas correspond to the areas not covered by the reduced wings).

Morphology.—Length of body: 2.5 mm. Vertex fairly sharp. Median epicranial suture and its anterior arms distinct, the latter strongly divergent. Frons large, postclypeus small. Head with strong pubescence, setae longer on vertex and lower parts of genae. Antennae long, of at least fifty segments in some specimens. Eyes almost reaching level of vertex. No ocelli. Lacinia (fig. 19). Maxillary palp second segment with short, stout, blunt spur on basal quarter, large external seta half way along, and two spurs near distal end; apical segment enlarged distally, obliquely truncate. Prothorax short, wider than the simple mesothorax. Measurements of hind leg: F: 0.70 mm; T: 0.88 mm; t_1: 0.37 mm; t_2: 0.07 mm; t_3: 0.07 mm; rt: 5.3:1:1. Hind femora somewhat enlarged, noticeably so in comparison with femora of other legs. Hind tibiae strongly spinose on dorsal side; apex of tibia with one small and two large spines. Claws with small preapical tooth basad of which are a few very small denticles. Fore wing length: 1.30 mm; fore wing width: 0.55 mm. Fore wing (fig. 18) convex, elytriform, reduced, narrowing to a bluntly rounded apex; coastal and anal margins thickened to form a marginal flange in basal two-thirds, distally the ridge is less obvious; coastal flange more strongly developed than anal flange. No trace of veins; wing surface with closely set, narrow scales based on small alveoli; at nearly equal intervals over the whole surface, more widely spaced, stout, erect setae, based on large alveoli, protrude through the mat of scales to give an array of spines; scales and setae easily detached; few remain on most of the preserved specimens. Hind wing a very small membranous flap. Abdomen well sclerotized ventrally, dorsally membranous except for those areas which are not covered by the short wings. Scales occur on limited areas of the body only, those of the legs are long and narrow, those of the abdomen are broader. Epiproct simple. Paraproct simple, sparsely setose, with two setae arising from "rosette" bases. Posterior spine of paraproct (fig. 20) broad-based, narrowing sharply basally, more distally the shaft tapers gradually to a fine point. Hypandrium simple. Phallosome (fig. 21).

FEMALE

Coloration (in alcohol).—As male.

Morphology.—Length of body: 2.5 mm. General morphology as male. Measurements of allotype female very close to those of holotype male. Epiproct simple, sparsely setose with two small convergent setae in middle of the hind margin. Paraproct simple, two setae with "rosette" bases; spine as male. Ninth tergite strongly sclerotized. Subgenital plate membranous except for a semicircular, sclerotized plate. Gonapophyses (fig. 22) with dorsal valve remnants and a distally tapering, setose, external valve.

MATERIAL EXAMINED

Norfolk Island: 5 ♂ (including holotype), 5 ♀ (including allotype), Rocky Point Reserve, 23.xi.1968 (G. F. Smithers). Holotype, allotype, and paratypes in Australian Museum.

DISCUSSION

This species is placed in *Lepolepis* Enderlein although the wings are not as reduced as in the type species, *L. ceylonica* Enderlein (from Ceylon) and *L. bicolor* Broadhead (from imported West African ground nuts in Britain). *L. occidentalis* Mockford (from North America) has wing veins and is polymorphic. *L. graemei* shares with the type species scale distribution and form, excessive number of antennal segments and reduced elytriform and veinless wings. It can be distinguished from the other species in the genus by the form and colour-pattern of the fore wings.

CAECILIIDAE

Caecilius insulatus sp. n.

MALE

Coloration (in alcohol).—Head testaceous with slightly darker clouding across vertex in well pigmented specimens. Ocellar tubercle pale brown. Antennae brown, darker than ocellar tubercle. Eyes black. Maxillary palp as head, pale brown in well pigmented specimens. Mesothoracic lobes brown, broad areas adjacent to sutures testaceous. Thorax otherwise as head. Legs uniformly pale greyish-brown. Fore wings (fig. 23) hyaline, very faintly and uniformly tinged with brown. Veins, except cu_2, brown. Hind wings hyaline, veins brown.

Morphology.—Length of body: 1.7–1.9 mm. Vertex smoothly rounded. Median epicranial suture distinct. Ocellar tubercle prominent. Postclypeus slightly bulging. Labrum with very well developed disto-lateral styli. Antennae with basal flagellar segments thickened; distal segments narrower, antennae thus strongly tapering. Lengths of flagellar segments: f_1: 0.336 mm; f_2: 0.266 mm. Basal flagellar segment slightly curved, second segment straight Eyes moderately large, not quite reaching level of vertex IO/D: 1.8; PO: 0.75. Lacinia (fig. 24).

Mesothoracic precoxal suture discernible as a faint groove. Fore and middle tibiae of even width along length. Measurements of hind leg: F: 0.294 mm; T: 0.784 mm; t_1: 0.238 mm; t_2: 0.112 mm; rt: 2.1:1; ct: 16, 0. Fore wing length: 2.00 mm; fore wing width: 0.72 mm. Position of fore wing radial fork (fig. 23) varies, but always well basad of origin of m_3; pterostigma and veins with strong setae, except cu_2 which is glabrous. Hind wing length: 1.52 mm; hind wing width: 0.52 mm. Setae on margin of hind wing from r_1 to wing apex denser than elsewhere. Epiproct (fig. 25). Paraproct with large circular trichobothrial field, the setae long and slender; field of papillae small, with small papillae. Phallosome (fig. 26). Hypandrium with marginal setae somewhat concentrated laterally leaving a median gap.

FEMALE

Coloration (in alcohol).—Similar to male.

Morphology.—Length of body: 1.7–1.8 mm. General features as male, ocellar tubercle a little less prominent and antennae a little finer and shorter. Lengths of flagellar segments: f_1: 0.196 mm; f_2: 0.154 mm. Eyes only a little smaller than in male, not reaching level of vertex. IO/D: 2.4; PO: 0.9. Measurements of hind leg: F: 0.378 mm; T: 0.658 mm; t_1: 0.196 mm; t_2: 0.084 mm; rt: 2.3:1, ct: 12, 0. Fore wing length: 1.8 mm; fore wing width: 0.6 mm. Fore wings with *rs-m* confluence shorter than in male and radial fork about opposite to origin of m_3. Hind wing length: 1.36 mm; hind wing width: 0.44 mm. Epiproct and paraproct without papillar fields; trichobothrial field small, with a central seta lacking a "rosette" base. Subgenital plate simple. Gonapophyses (fig. 27). Spermathecal sac spherical, glandular area of duct long, almost reaching sac.

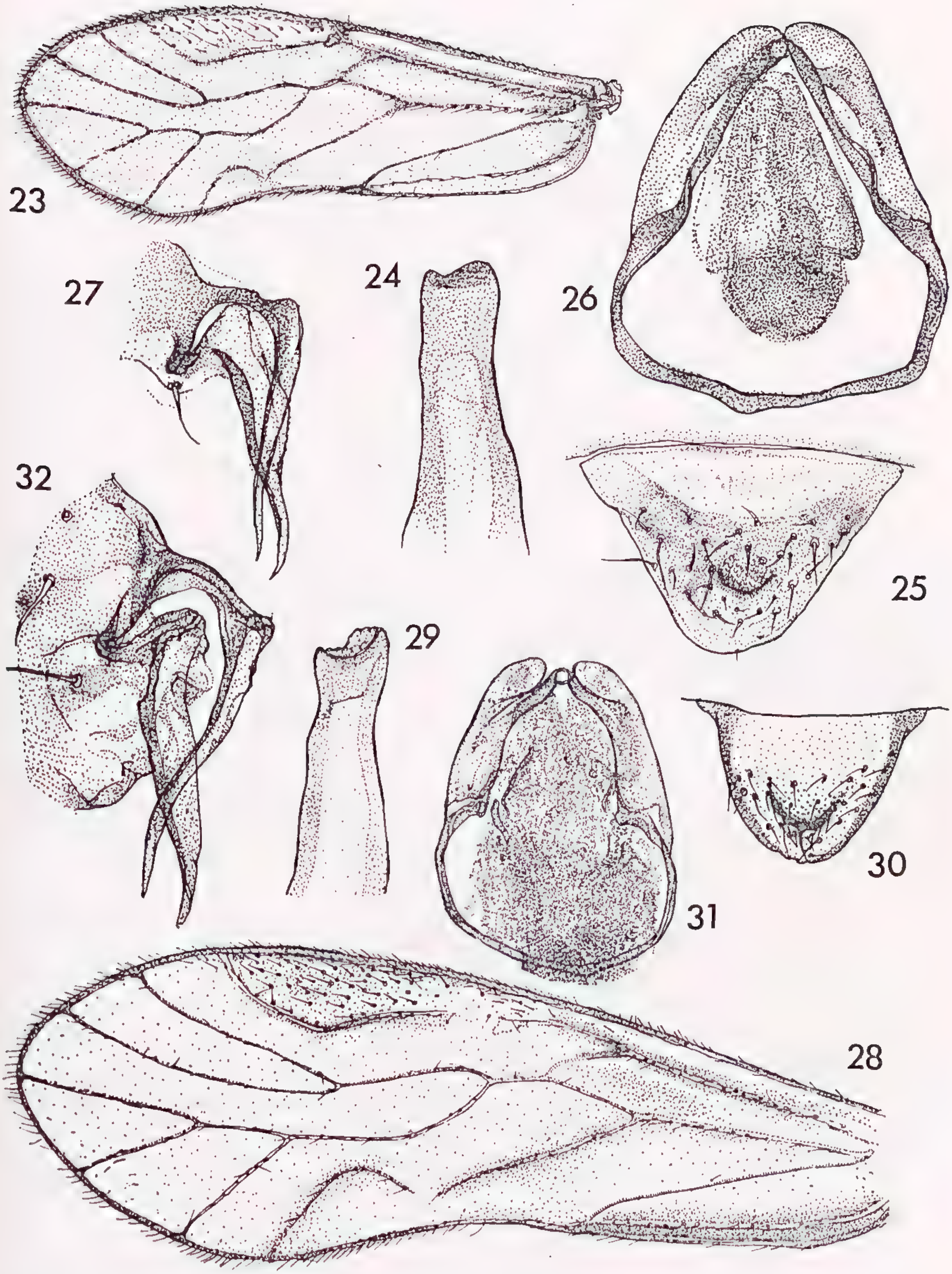
MATERIAL EXAMINED

Norfolk Island: 5 ♂ (including holotype), 3 ♀ (including allotype), Captain Cook Monument, 31.viii.1971; 6 ♂, 4 ♀, Selwyn Reserve, 30.viii.1971; 5 ♂, 5 ♀, Rocky Point Reserve, 28.viii.1971; 5 ♂, 3 ♀, Cascade-Red Rd, 28.viii.1971; 1 ♀, Mount Pitt to Mount Bates path, 2.ix.1971; 5 ♂, 5 ♀, Bumbora, 26.viii.1971; 2 ♂, 3 ♀, Point Blackbourne, 25.viii.1971; 6 ♂, 5 ♀, Mount Bates Rd, 29.viii.1971; 1 ♀, ex Cypress trees, Mission Rd, 28.viii.1971 (C. N. Smithers and I. W. B. Thornton); 2 ♀, Rocky Point Reserve, 23.xi.1968 (C. N. Smithers); 1 ♀, Burnt Pine, 21.xi.1968 (A. S. Smithers).

Holotype, allotype, and paratypes in Australian Museum, paratypes in Australian National Insect Collection, British Museum and Bernice P. Bishop Museum.

DISCUSSION

Caecilius is a large genus, but *Caecilius insulatus* differs from those species with which it might be confused as follows. It differs from the following in lacking a head pattern: *C. casarum* Badonnel, *C. dubius* Badonnel, *C. arotellus* Banks and *C. pallidobrunneus* Mockford. It is much smaller than *C. ademimensis* Badonnel, *C. castellus* Banks, *C. gilvus* Pearman, *C. luridus* Enderlein, *C. brevihirtus* Banks, *C. luteovenosus* Okamoto, *C. kamakurensis* Okamoto, *C. graminis* Mockford and *C. annulicornis* Enderlein. It differs in colour from *C. tamiami* Mockford, *C. incoloratus* Mockford and *C. imbecillus* McLachlan.



Figs 23–27. *Caecilius insulatus* sp. n. 23, ♂ fore wing; 24, ♂ lacinia; 25, ♂ epiproct; 26, ♂ phallosome; 27, ♀ gonapophyses. Figs 28–32. *Caecilius pacificus* sp. n. 28, ♂ fore wing; 29, ♂ lacinia; 30, ♂ epiproct; 31, ♂ phallosome; 32, ♀ gonapophyses.

Caecilius pacificus sp. n.

MALE

Coloration (in alcohol).—Head yellowish. Antennae dark brown. Eyes black. Ocellar tubercle pale, inner margins of ocelli brown. Maxillary palps yellowish, with faint brownish tinge near apex of fourth segment. Thorax yellowish with dark brown antedorsum and lateral lobes. Prothoracic legs with femur yellowish; tibia and tarsus faintly tinged with brown. Meso- and metathoracic legs yellowish, with only second tarsal segment tinged with brown. Fore wing (fig. 28) hyaline, tinged generally with very faint yellow, markings in various shades of brown, the darkest being cell Cu_2. Veins brownish. Abdomen yellowish.

Morphology.—Length of body: 2.4 mm. Median epicranial suture indistinct. Vertex somewhat flattened between eyes. Labrum without disto-lateral styli. Lengths of flagellar segments: f_1: 0.728 mm; f_2: 0.630 mm. Basal and second flagellar segments thickened, especially basal segment which is also noticeably curved; finely and densely pubescent. Eyes large, extending a little beyond level of vertex. IO/D: 0.58; PO: 0.83. Lacinia (fig. 29). Mesothoracic precoxal suture distinct. Tibiae of prothoracic legs not swollen. Measurements of hind leg: F: 0.616 mm; T: 1.100 mm; t_1: 0.350 mm; t_2: 0.112 mm; rt: 3.1:1; ct: 21, 0. Fore wing length: 3.0 mm; fore wing width: 1.0 mm. Fore wing with *rs* and *m* fused for a considerable length, *rs* fork well basad of origin of m_3; r_{2+3} curving a little forward in distal quarter; r_{4+5} smoothly but slightly curved throughout its length. Hind wing length: 2.2 mm; hind wing width: 0.68 mm. Veins *rs* and *m* in hind wing fused for a long length. Epiproct (fig. 30). Paraproct with small papillae occupying a circular area, bearing a well developed cone on hind margin. Hypandrium simple, sparsely setose, with slight lateral concentration of marginal setae. Phallosome (fig. 31).

FEMALE

Coloration (in alcohol).—As male, but in well pigmented specimens a very faint darkening across vertex adjacent to epicranial suture and on postclypeus. Antenna with f_1 and f_2 paler than more distal segments which are dark brown.

Morphology.—Length of body: 2.6 mm. Median epicranial suture distinct, more so than in male. Lengths of flagellar segments: f_1: 0.63 mm; f_2: 0.49 mm. Eyes smaller than male, just reaching level of vertex. IO/D: 1.4; PO: 0.77. Basal and second flagellar segments only a little thickened and hardly curved. Measurements of hind leg: F: 0.658 mm; T: 1.060 mm; t_1: 0.336 mm; t_2: 0.112 mm; rt: 3.0:1; ct: 18, 0. Fore wings as in male. Fore wing length: 3.20 mm; fore wing width: 1.04 mm. Hind wing length: 2.44 mm; hind wing width: 0.76 mm. Subgenital plate with small lateral apophyses and little pigmentation, even in well-pigmented specimens. Gonapophyses (fig. 32). Spermathecal sac spherical, glandular area of duct long and reaching almost to sac.

MATERIAL EXAMINED

Norfolk Island: 19 ♂ (including holotype), 27 ♀ (including allotype), Selwyn Pine Rd, 31.viii.1971; 2 ♂, 7 ♀, Captain Cook Monument, 31.viii.1971; 8 ♂, 10 ♀, Rocky Point Reserve, 28.viii.1971 and i.ix.1971; 6 ♂, 15 ♀, in garden, Aunt Em's Guesthouse, Burnt Pine, 3.ix.1971; 1 ♀, Selwyn Reserve, 30.viii.1971; 3 ♂, 2 ♀, Stockyard Creek, 25.viii.1971; 1 ♂, Collin's Head, 30.viii.1971; 2 ♂, 1 ♀, Mount

Bates Rd, 29.viii.1971; 1 ♂, 2 ♀, N. of Ball Bay, 3.ix.1971; 2 ♂, 2 ♀, Mount Pitt-Mount Bates path, 2.ix.1971; 2 ♂, 1 ♀, Mount Pitt, 29.viii.1971 (C. N. Smithers and I. W. B. Thornton); 8 ♂, 11 ♀, Palm Glen, 22–24.xi.1968; 1 ♂, 9 ♀, Rocky Point Reserve, 21–23.xi.1968 (C. N. and A. S. Smithers); 1 ♂, Bumbora, 18.xi.1968; 7 ♂, 5 ♀, 21–29.x.1967; 1 ♀, Mount Pitt, 23.iii.1969; 3 ♂, 6 ♀, Captain Cook Monument, 22.xi.1968; 4 ♂, 4 ♀, Point Ross, 27.xi.1968 (C. N. Smithers); 1 ♂, Mount Pitt, 19.xi.1968; 1 ♂, 6 ♀, Melanesian Mission, 20.xi.1968; 1 ♂, 1 ♀, Point Ross, 24.xi.1968; 2 ♂, 7 ♀, Bumbora, 18.xi.1968 (A. S. Smithers); 1 ♂, 1 ♀, Rocky Point Reserve, 23.xi.1968; 1 ♀, Mount Pitt, 19.xi.1968 (G. F. Smithers).

Holotype, allotype, and paratypes in Australian Museum, paratypes in Australian National Insect Collection, British Museum and Bernice P. Bishop Museum.

DISCUSSION

Caecilius pacificus is similar to *C. flavistigma* (Tillyard) in general appearance, but differs in lacking the bold median longitudinal brown stripe on the head.

ECTOPSOCIDAE

Ectopsocus briggsi McLachlan

MATERIAL EXAMINED

Norfolk Island: 5 ♂, 8 ♀, Ross Point, 24.xi.1968, 1 ♂, 1 ♀, Rocky Point Reserve, 21.xi.1968; 4 ♂, 3 ♀, Burnt Pine, 21.xi.1968; 1 ♂, 2 ♀, Palm Glen, 22.xi.1968; 1 ♀, Melanesian Mission, 20.xi.1968; 1 ♀ Anson Bay, 23.xi.1968; 3 ♂, 2 ♀, Mount Pitt, 21.xi.1968 (A. S. Smithers); 24 ♂, 51 ♀, Rocky Point Reserve, 23.xi.1968; 4 ♀, Captain Cook Monument, 22.xi.1968; 1 ♂, 2 ♀, Ross Point, 27.xi.1968 (C. N. Smithers); 1 ♂, 1 ♀, Mount Pitt, 19.xi.1968; 1 ♂, 3 ♀, Rocky Point Reserve, 23.xi.1968 (G. F. Smithers); 35 ♂, 63 ♀, Rocky Point Reserve, 1.ix.1971; 5 ♀, in garden, Aunt Em's Guest House, Burnt Pine, 3.xi.1971; 1 ♂, Captain Cook Monument, 31.viii.1968; 3 ♀, Selwyn Pine Road, 31.viii.1971; 1 ♂, Mount Pitt, 29.viii.1971; 1 ♂, 2 ♀, Mt Bates Road, 29.viii.1971; 8 ♂, 5 ♀, Mount Pitt-Mt Bates path, 2.ix.1971 (C. N. Smithers and I. W. B. Thornton).

E. briggsi is a widespread species known from Africa, Europe, North and South America, Australia, India, Micronesia, and New Zealand.

Ectopsocus insularis sp. n.

MALE

Coloration (in alcohol).—Head pale buff with pale brown area either side of epicranial suture, adjacent to compound eyes and across back of vertex. Frons very pale buff. Postclypeus very pale brown. Labrum very pale brown. Genae coloured as frons. Antennae brown. Eyes black. Ocelli colourless, on pale brown tubercle. Maxillary palps pale brown with colourless tip. Legs very pale brown. Fore wings (fig. 33) hyaline, tinged with very pale grey which is palest in median and cubital cells near wing margin and darkest at proximal end of pterostigma, *rs-m* meeting point and adjacent to veins distally. Hind wings hyaline, veins brown. Abdomen very pale, the phallosome sclerifications visible through the brown hypandrium and the tubercles and comb of the ninth tergite visible as black marks under low power (x8).

Morphology.—Length of body: 1.5 mm. Lengths of flagellar segments: f_1: 0.275 mm; f_2: 0.190 mm. Eyes moderately large, just reaching level of vertex, almost circular when seen from above. IO/D: 1.66; PO: 0.75. Measurements of hind leg: F: 0.325 mm; T: 0.590 mm; t_1: 0.212 mm; t_2: 0.075 mm; rt: 2.9:1; ct: 16, 1. Fore wing length: 1.6 mm; fore wing width: 0.6 mm; pterostigma broadening slightly in distal part; veins *rs* and *m* fused for a short length, *rs* fork opposite a point between origins of m_2 and m_3; wing margin glabrous, a few short setae on all veins except cu_2. Hind wing length: 1.2 mm; hind wing width: 0.4 mm; margin and veins glabrous. Ninth tergite (fig. 34) trapezoid with a proximal group of tubercles and a strong comb along hind border. Epiproct simple, with rounded hind margin, lightly sclerotized, sparsely setose. Phallosome (fig. 35) with external parameres sinuous, tapering, sharply pointed; sclerifications of penial bulb complex.

FEMALE

Coloration (in alcohol).—As male, but at apex of abdomen the remarkably strong, asymmetrical sclerifications of the inner part of the subgenital plate show through as strong brown markings on the right side, being easily visible even in otherwise pale individuals.

Morphology.—Length of body: 1.7 mm. Antennae finer than in male. Lengths of flagellar segments: f_1: 0.25 mm; f_2: 0.18 mm. Eyes smaller than in male, not quite reaching level of vertex. IO/D: 2.4; PO: 0.6. Measurements of hind leg: F: 0.325 mm; T: 0.600 mm; t_1: 0.190 mm; t_2: 0.060 mm; rt: 3.1:1; ct: 15, 0. Fore wing length: 1.7 mm; fore wing width: 0.6 mm. Wing form, setae and venation as in male but *rs* and *m* fused for a very short length. Hind wing length: 1.4 mm; hind wing width: 0.5 mm. Epiproct simple, rounded behind, lightly sclerotized, with ovoid, very lightly sclerotized area in distal third, posterior margin of ovoid area reaching hind margin; two strong posterior marginal setae flank a small median seta; four long setae occur on either side near lateral margins of epiproct. Paraproct with few trichobothria and a row of six strong setae; hind margin bears one strong seta, a very small, double cone adjacent to a much reduced seta and a few small setae ventrally. Subgenital plate (fig. 36) bilobed, each lobe bearing a strong terminal seta and one smaller seta on inner margin and two on outer margin; preapical row of small setae, posterolateral margins of plate strengthened by a sclerotized rod and internal face sclerotized in a remarkable, asymmetrical fashion, dark sclerotized areas being clearly visible through subgenital plate. Gonapophyses (fig. 37).

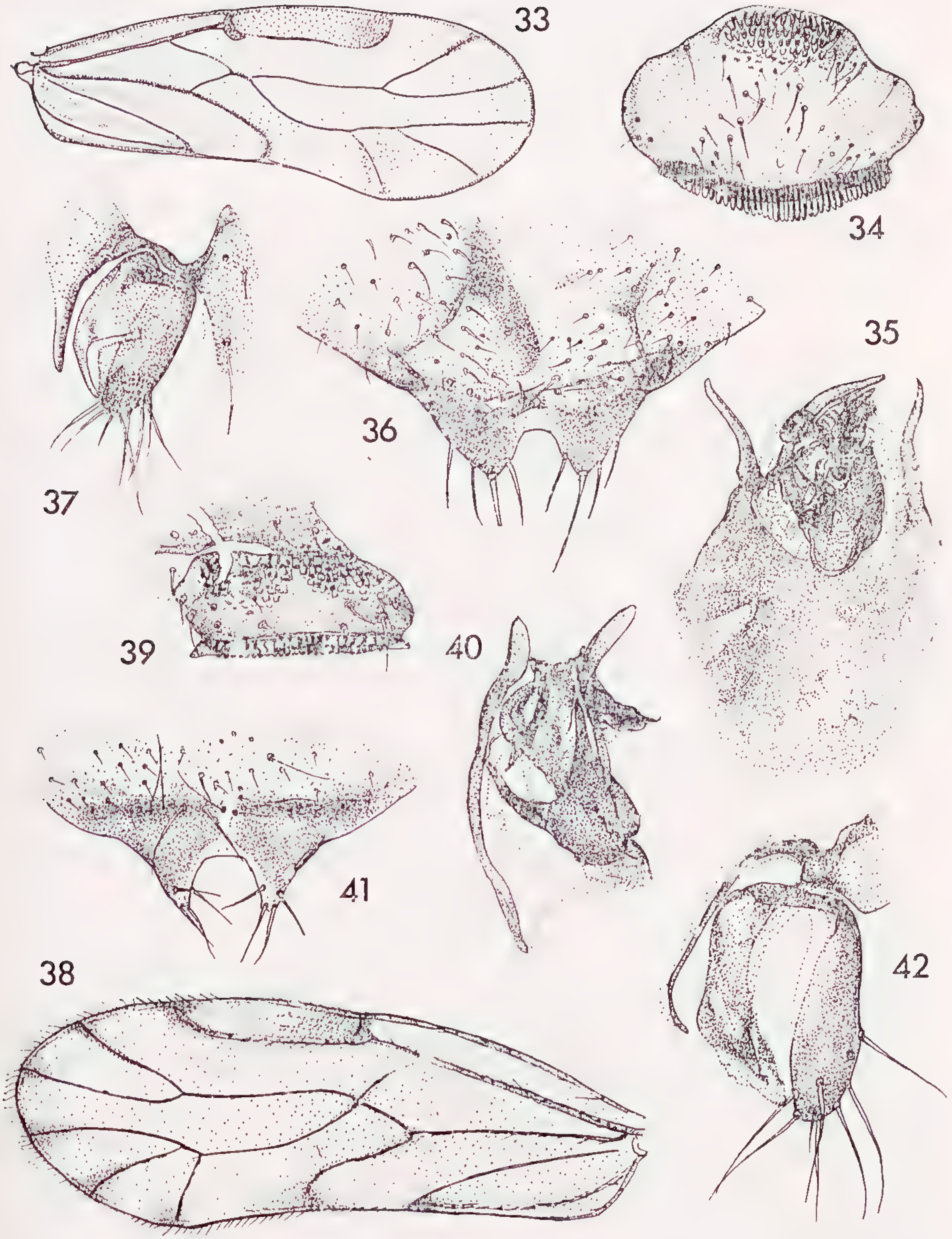
MATERIAL EXAMINED

Norfolk Island: 1 ♂ (holotype), 9 ♀ (including allotype), in garden, Aunt Em's Guest House, Burnt Pine, 3.ix.1971 (C. N. Smithers and I. W. B. Thornton); 1 ♀, Melanesian Mission, 20.xi.1968; 2 ♀, Bumbora, 18.xi.1968; 2 ♀, Anson Bay, 23.xi.1968 (A. S. Smithers); 6 ♀, Rocky Point Reserve, 23.xi.1968 (C. N. Smithers).

Holotype, allotype, and paratypes in Australian Museum, paratypes in Australian National Insect Collection.

DISCUSSION

Ectopsocus insularis belongs to the *ornatus* group of species as defined by Thornton and Wong (1968, p. 140). The male resembles the other species in the general form of the sclerifications of the penial bulb but differences of detail are evident in these complex structures in each species. The shape of the field of tubercles on the ninth



Figs 33–37. *Ectopsocus insularis* sp. n. 33, ♂ fore wing; 34, ♂ 9th tergite; 35, ♂ phallosome; 36, ♀ subgenital plate; 37, ♀ gonapophyses. Figs 38–42. *Ectopsocus inornatus* sp. n. 38, ♂ fore wing; 39, ♂ 9th tergite; 40, ♂ phallosome; 41, ♀ subgenital plate; 42, ♀ gonapophyses.

tergite differs from the other species, being nearest to that of *E. ornatoides* Thornton and Wong. The female is remarkable for the conspicuous, peculiar, asymmetrical sclerifications of the inner lining of the subgenital plate and the strengthening rods along its postero-lateral margins. The *ornatus* group of species is known from Hong Kong, Taiwan, the Marshalls and Gilberts, Fiji, Samoa, Hawaiian Islands, and the Kermadecs. *E. insularis* is most similar to *E. ornatoides*, which is known from Micronesia, Fiji, Samoa, and the Hawaiian Islands.

Ectopsocus inornatus sp. n.

MALE

Coloration (in alcohol).—Head light buff with very slightly darker areas near eyes, median epicranial suture and frons. Epistomial suture dark, thus giving a dark, curved line between antennae bases. Postclypeus, anteclypeus and labrum pale, without markings on postclypeus. A dark mark connects antennal bases and compound eyes. Genae pale. Antennae brown. Ocelli pale, on a pale tubercle but margined centripetally with dark brown crescents. Eyes black. Maxillary palps pale. Thorax pale brown above, clearly darker than head under low power (x8). Thorax laterally with a longitudinal dark brown stripe; seen from the side, the insect thus has a stripe from antenna base, through eye and along side of the body to base of abdomen. Legs very pale, the tibiae a little darker than the other segments. Fore wing (fig. 38) hyaline, faintly tinged with yellowish brown, marked with darker areas as in figure. Hind wings hyaline with ill-defined darker areas bordering apices of r_{2+3}, r_{4+5}, m and cu_1. Abdomen pale, with irregular, segmental brown markings; apex of abdomen dark due to sclerotization of hypandrium, tergite and other terminal structures.

Morphology.—Length of body: 1.7 mm. Head with long sparse setae on vertex and frons; shorter setae on postclypeus. Lengths of flagellar segments: f_1: 0.41 mm; f_2: 0.26 mm. Eyes fairly large, hemispherical, but not reaching level of vertex; inner margins diverge very slightly when viewed from above. IO/D: 2.3, PO: 0.66. Measurements of hind leg: F: 0.425 mm; T: 0.700 mm; t_1: 0.42 mm; t_2: 0.06 mm; rt: 7:1; ct: 17, 0. Fore wing length: 2.0 mm; fore wing width: 0.7 mm. Fore wing (fig. 38) with *rs* and *m* meeting in a point; pterostigma a little broader towards distal end; r_{2+3} slightly sinuous; cu_1 strongly recurved near wing margin; wing margin setose, with additional setae from distal end of pterostigma to wing apex; veins setose. Hind wing length: 1.5 mm; hind wing width: 0.5 mm. Hind wing margin with setae between r_1 and r_{4+5}; cu_1 more strongly developed than other veins. Epiproct simple, rounded posteriorly with a group of six small setae in distal half and two long posterior marginal setae. Paraproct with oval field of about eight trichobothria with a small simple seta ventrad of field; paraproct has only one large seta in addition to the usual small setae near the posterior margin; a large double cone and small adjacent setae on margin. Hypandrium simple, hind margin more strongly sclerotized laterally than mesially. Ninth tergite (fig. 39) with a strongly sclerotized extensive oval area which is strongly sculptured in a regular pattern; posterior comb reduced to a row of small, rounded tubercles. Phallosome (fig. 40) with apically broadened external parameres, interior parameres fused into a median plate with a posterior tooth on each side; sclerifications of penial bulb complex; phallosome strongly upcurved posteriorly, so that external parameres are almost pointing upwards.

FEMALE

Coloration (in alcohol).—As male.

Morphology.—General features as male. Length of body: 1.9 mm. Lengths of flagellar segments: f_1: 0.400 mm; f_2: 0.212 mm. Antennae finer than male. Eyes smaller than male. IO/D: 4.0; PO: 1.5. Measurements of hind leg: F: 0.50 mm; T: 0.70 mm; t_1: 0.20 mm; t_2: 0.09 mm; rt: 2.2:1; ct: 16, 0. Fore wing length: 2.0 mm; fore wing width: 0.7 mm. Hind wing length: 1.5 mm; hind wing width: 0.5 mm. Venation and setae as male. Epiproct broad, trapezoid, with four strong setae in basal half, two on each side, and a row of smaller posterior, marginal setae. Paraproct with almost round field of eight trichobothria and row of five, strong setae; posterior double cones short and stout, with one small seta close to them and flanked by two larger setae. Subgenital plate (fig. 41) with four strong setae on each lobe, two terminal and two arising well basad of end of lobe. Gonapophyses (fig. 42).

MATERIAL EXAMINED

Norfolk Island: 6 ♂ (including holotype), 3 ♀ (including allotype), Mount Pitt, 21.xi.1968; 1 ♀, Palm Glen, 22.xi.1968 (A. S. Smithers); 1 ♂, 1 ♀, Captain Cook Monument, 22.xi.1968 (C. N. Smithers); 1 ♂, 3 ♀, Mount Pitt Reserve, 28.viii.1971 (C. N. Smithers and I. W. B. Thornton).

Holotype, allotype, and paratypes in Australian Museum; paratypes in Australian National Insect Collection.

DISCUSSION

E. inornatus resembles *E. nidicolus* Thornton and Wong (from New Guinea) and agrees well with the definition of the *E. basalis* group in which *E. nidicolus* is included (Thornton and Wong, 1968). It differs, however, in details of the sclerification of the penial bulb and in having marginal setae on the hind wing between r_1 and r_{4+5}. The *E. basalis* group includes species from the Philippines, New Guinea, the Caroline Islands, and Malaya.

PERIPSOCIDAE

Peripsocus milleri (Tillyard)

MATERIAL EXAMINED

Norfolk Island: 1 ♀, Mount Pitt, 29.viii.1971 (C. N. Smithers and I. W. B. Thornton).

This species has been recorded from New Zealand and Western Australia.

Peripsocus norfolkensis sp. n.

MALE

Coloration (in alconol).—Head pale brown with broad dark brown mark each side of median epicranial suture and dark brown spot on vertex near each eye; a small brown spot abuts inner margin of compound eye opposite anterior end of median epicranial suture. Frons very pale brown in middle, dark brown laterally. Postclypeus very pale with a broad, irregular dark brown band each side mesad of antennal bases from epistomial suture to anterior margin of postclypeus. A brown

mark connects this band to eye just above antennal base. Anteclypeus pale; labrum brown. Genae very pale. Antennae brown. Eyes black. Maxillary palps brown. Mesothoracic notum brown, pale adjacent to sutures and with median, longitudinal pale stripe on antedorsum. Legs brown, femora a little paler than other segments. Fore wings (fig. 43) hyaline, slightly testaceous; pterostigma with dark spot at base, dark pigment along r_1 from hind angle to costal margin, a dark spot at nodulus; veins brown except *m* between separation from *rs* and m_3, which is pale. Thorax brown laterally with darker lateral stripe. Abdomen pale, almost colourless; terminal structures dark brown.

Morphology.—Length of body: 1.6 mm. Head small, eyes conspicuous. Antennae short, 1.6 mm, shorter than fore wing. Lengths of flagellar segments: f_1: 0.22 mm; f_2: 0.22 mm. Eyes large, reaching just beyond level of vertex; when viewed from above inner margins convex, hind margins strongly divergent. IO/D: 0.86; PO: 1.00. Abdomen slender, cylindrical. Measurements of hind leg: F: 0.322 mm; T: 0.650 mm; t_1: 0.175 mm; t_2: 0.087 mm; rt: 2:1; ct: 17, 1. Fore wing length: 2.0 mm; fore wing width: 0.8 mm, fore wings broad; costa thickened for a length basad of pterostigma; veins *rs* and *m* fused for a length, *rs* divides opposite hind angle of pterostigma, m_3 arises opposite *rs* bifurcation; veins well defined but *m* distad of separation from *rs* somewhat evanescent and pale as far as origin of m_3; m_1 reaches margin at wing apex. Hind wing length: 1.6 mm; hind wing width: 0.6 mm. Epiproct semi-circular, sclerotized, with a few fine setae along posterior margin. Hypandrium simple, rather more lightly sclerotized in middle than laterally. Phallosome (fig. 44) with broad anterior end, with complex and characteristic sclerification of the penial bulb. No caudal comb on ninth tergite.

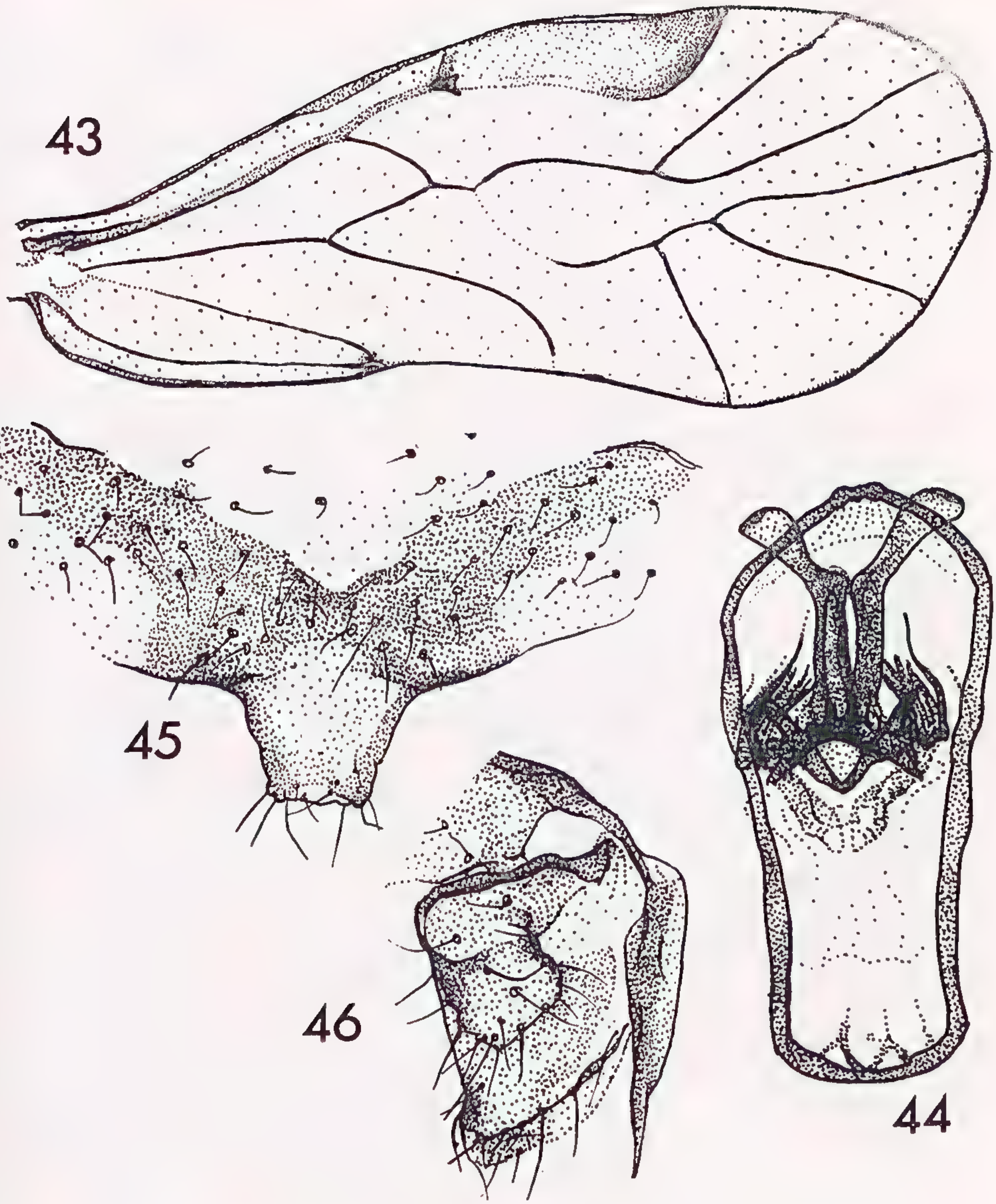
FEMALE

Coloration (in alcohol).—Head similar to male but spot near inner margin of eyes much bigger and more conspicuous owing to reduced area of head occupied by eyes. Genae with dark brown spot at lower end. Abdomen almost colourless dorsally and ventrally as male but with distinct lateral segmental bands of brown.

Morphology.—Length of body: 1.7 mm. Antennae shorter than fore wings. Lengths of flagellar segments: f_1: 0.220 mm; f_2: 0.175 mm. Eyes small, much smaller than male, not reaching level of vertex. IO/D: 4.0; PO: 0.75. Measurements of hind leg: F: 0.322 mm; T: 0.622 mm; t_1: 0.175 mm; t_2: 0.087 mm; rt: 2:1; ct: 12, 0. Fore wing length: 2.2 mm; fore wing width: 1.3 mm; fore wing form and venation similar to male. Hind wing length: 1.6 mm; hind wing width: 0.6 mm. Subgenital plate (fig. 45). Gonapophyses (fig. 46) with well developed ventral valve; dorsal valve broad with small, apparently separate, posterior accessory sclerite; outer valve small, very lightly sclerotized, short and broad.

MATERIAL EXAMINED

Norfolk Island: 5 ♂ (including holotype), 11 ♀ (including allotype), Stockyard Creek, 25.viii.1971 (C. N. Smithers and I. W. B. Thornton); 4 ♂, 13 ♀, Point Ross, 24.xi.1968; 1 ♂, 3 ♀, Palm Glen, 24.xi.1968; 1 ♂, 2 ♀, Burnt Pine, 21.xi.1968; 10 ♀, Melanesian Mission, 20.xi.1968 (A. S. Smithers); 2 ♂, 2 ♀, Mount Pitt, 23.iii.1969; 1 ♀, Jonneniggabunnit, 24.iii.1969; 3 ♀, Point Ross, 27.xi.1968; 1 ♂, Collin's Head, 24.iii.1969; 15 ♂, 6 ♀, 21–29.x.1967 (C. N. Smithers); 1 ♂, 1 ♀, Selwyn Pine Road, 31.viii.1971; 2 ♂, 5 ♀, Rocky Point Reserve, 28.viii.1971; 1 ♂, 1 ♀, Captain Cook Monument, 31.viii.1971; 1 ♂, in garden, Aunt Em's Guesthouse, Burnt Pine, 3.ix.1971; 2 ♀, *ex* Cypress trees, Mission Rd, 28.viii.1971 (C. N. Smithers and I. W. B. Thornton); 1 ♂, Mount Pitt forest, 17.iv.1972; 1 ♀, Anson Bay Rd, 13.iv.1972; (A. L. Dyce, H. A. Standfast, and P. Ferrar).



Figs 43–46. *Peripsocus norfolkensis* sp. n. 43, ♂ fore wing; 44, ♂ phallosome; 45, ♀ subgenital plate; 46, ♀ gonapophyses.

Holotype, allotype, and paratypes in Australian Museum, paratypes in Australian National Insect Collection, British Museum, and Bernice P. Bishop Museum.

DISCUSSION

Peripsocus norfolkensis can be distinguished from other species of the genus by the form of the phallosome in the male and the gonapophyses in the female. The only species with which it is likely to be confused is *P. maoricus* (Tillyard) from New Zealand which, however, has three small lobes on the posterior end of the phallic frame and lacks the multipointed parts of the sclerification of the penial bulb in the male. The proportions of the lobe of the subgenital plate differ in the two species and in females of *P. maoricus* there is a definite darkening of the wing membrane in a band running from basad of the pterostigma towards the nodulus (of Smithers, 1969, figs 96–101). *P. norfolkensis* and *P. maoricus* are closely related species.

PSEUDOCAECILIIDAE

Heterocaecilius variabilis sp. n.

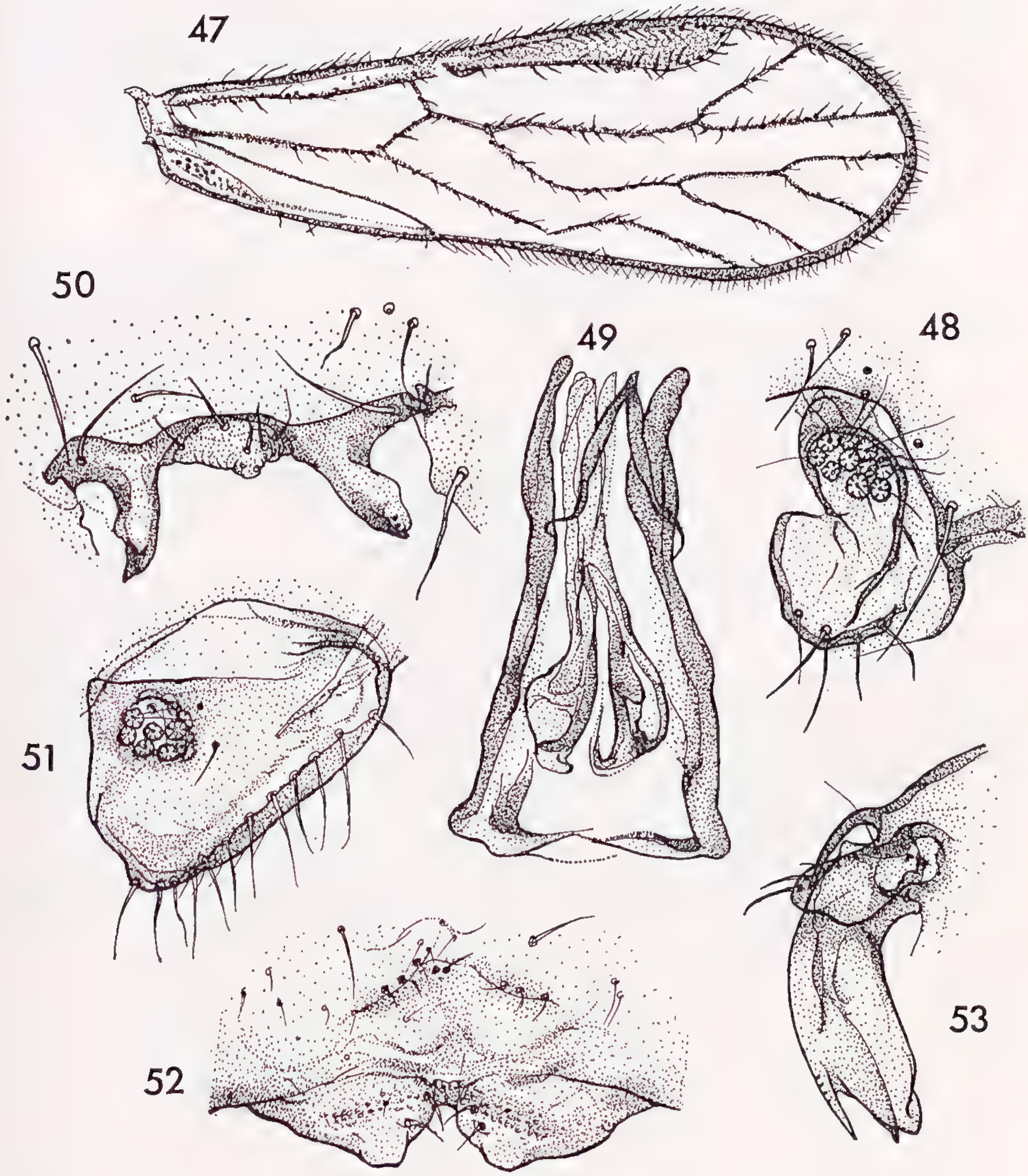
MALE

Coloration (in alcohol).—Coloration variable, possibly dependant on age. Some specimens almost uniformly very pale buff, with almost colourless antennae and black eyes; apex of abdomen a little darker due to strong sclerotization of ninth tergite, especially its anterior border. Specimens with greater pigment deposition have head very pale buff with brown mark across vertex, darker mesially than nearer the eyes; antennae pale brown, eyes black; Ocelli colourless with borders adjacent to one another marked with very dark brown (the marks occur also in the paler specimens and stand out in sharp contrast to the rest of the head). Maxillary palps pale. Mesonotum dark brown, pale along sutures. Legs pale, tibiae a little darker than other segments. Fore wing (fig. 47) hyaline, colourless; pterostigma opaque white. Veins pale brown. Abdomen colourless, except for those terminal structures which are well sclerotized.

Morphology.—Length of body: 2.2 mm. Head with sparse, long, dark setae, symmetrically arranged. Lengths of flagellar segments: f_1: 0.55 mm; f_2: 0.35 mm. Eyes not quite reaching level of vertex. IO/D (Pearman): 1.7; IO/D (Badonnel): 1.3; PO: 0.75. Measurements of hind leg: F: 0.48 mm; T: 0.84 mm; t_1: 0.24 mm; t_2: 0.08 mm; rt: 3:1; ct: 13, 0. Fore wing length: 2.3 mm; fore wing width: 0.8 mm. Fore wing (fig. 47) with r_1 meeting wing margin at an acute angle; veins with strong setae in two series; vein r_{2+3} a little sinuous as are branches of *m;* areola postica long and flat; large field of sensilla in basal area of cell Cu_2 adjacent to anal vein; vein cu_2 without setae. Hind wing length: 1.9 mm; hind wing width: 0.6 mm. In hind wing veins *rs* and *m* fused for a long length; veins in distal part of wing setose. Epiproct semicircular, strongly sclerotized with a few setae and a median rugose area in posterior half; posterior margin with a row of strong, posteriorly directed setae. Paraproct (fig. 48). Phallosome (fig. 49). Hypandrium (fig. 50) with lightly sclerotized, lateral projecting bars ending in a strongly sclerotized lobe and tooth; posterior margin with small, single median projection. Ninth tergite strongly sclerotized, particularly along anterior margin; two small, rugose papillae adjacent to each side of base of epiproct.

FEMALE

Coloration (in alcohol).—As male but even in strongly pigmented specimens extent of dark areas on vertex is much less than in males, being limited to area near median epicranial suture.



Figs 47–53. *Heterocaecilius variabilis* sp. n. 47, ♂ fore wing; 48, ♂ paraproct; 49, ♂ phallosome; 50, ♂ hypandrium; 51, ♀ paraproct; 52, ♀ subgenital plate; 53, ♀ gonapophyses.

Morphology.—Length of body: 2.2 mm. Lengths of flagellar segments: f_1: 0.52 mm; f_2: 0.26 mm. Eyes small, much smaller than in males. IO/D (Pearman): 2.8; IO/D (Badonnel): 2.0; PO: 0.71. Measurements of hind leg: F: 0.46 mm; T: 0.74 mm; t_1: 0.24 mm; t_2: 0.1 mm; rt: 2.4:1; ct: 13, 0. Fore wing length: 2.20 mm; fore wing width: 0.64 mm. Fore wing venation and setae as male; no sensilla in cell Cu_2. Hind wing length: 1.60 mm; hind wing width: 0.44 mm; venation and setae as in male. Epiproct rounded posteriorly, lightly sclerotized with a transverse row of four strong setae near posterior margin and a few smaller marginal setae; a few small setae on body of epiproct basad of transverse row. Paraproct (fig. 51). Subgenital plate (fig. 52) with two posterior lobes each bearing three setae; a group of spicules occurs mesially at the bases of the lobes. Gonapophyses (fig. 53).

MATERIAL EXAMINED

Norfolk Island: 5 ♂ (including holotype), 8 ♀ (including allotype), Captain Cook Monument, 22.xi.1968 (C. N. Smithers); 1 ♂, Bumbora, 18.xi.1968; 1 ♀, Palm Glen, 22.xi.1968; 1 ♀, Burnt Pine, 21.xi.1968; 2 ♀, Mount Pitt, 19.xi.1968 (A. S. Smithers); 2 ♀, Rocky Point Reserve, 23.xi.1968; 1 ♀, 21–29.x.1967 (C. N. Smithers); 2 ♂, 1 ♀, Mount Pitt, 19.xi.1968 (G. F. Smithers); 1 ♂, Mount Pitt, 28.viii.1971; 4 ♂, 3 ♀, Selwyn Pine Rd, 31.viii.1971; 1 ♂, Captain Cook Monument, 31.viii.1971; 1 ♀, Mount Pitt, 29.viii.1971 (C. N. Smithers and I. W. B. Thornton).

Holotype, allotype, and paratypes in Australian Museum, paratypes in Australian National Insect Collection.

DISCUSSION

H. variabilis belongs to the *H. maculifrons* group as defined by Lee and Thornton (1967). It can be distinguished from other members of the group (other than *H. campanula* Lee and Thornton) by the form of the sclerification of the penial bulb and the form of the hypandrium, the absence of a preapical tooth on the tarsal claw and the presence of a field of sensilla in the male in cell Cu_2. In many features it resembles *H. campanula* which is clearly its nearest relative. It differs in size, however, and in the male having rugose areas of the ninth tergite on distinct papillae, also in the forms of the hypandrium, epiproct and paraproct. The female differs in lacking a sclerotized triangular area on each lobe of the subgenital plate, in having three large setae on each lobe and in the form of the paraproct. *H. campanula* is known from the Caroline Islands, the Marshalls, the Gilberts, and Kapingamaranga Atoll, that is, from Micronesia.

PHILOTARSIDAE

Haplophallus emmus sp. n.

FEMALE

Coloration (freshly killed, in alcohol).—Head cream, brown markings as in figures (54) and (55). Gena with a small brown patch at anterior corner. Eyes black, ocelli pale, ringed with black. Maxillary palp pale brown, apical segment dark brown. Antenna brown. Mesothorax with dark brown lobes, sutural areas and median stripe on antedorsum cream. Legs cream, banded brown, two bands on femur and three on tibia, femoral bands distinct on fore leg, confluent dorsally on hind leg, apical tibial band darker brown than rest. Fore wing markings as in

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58 59

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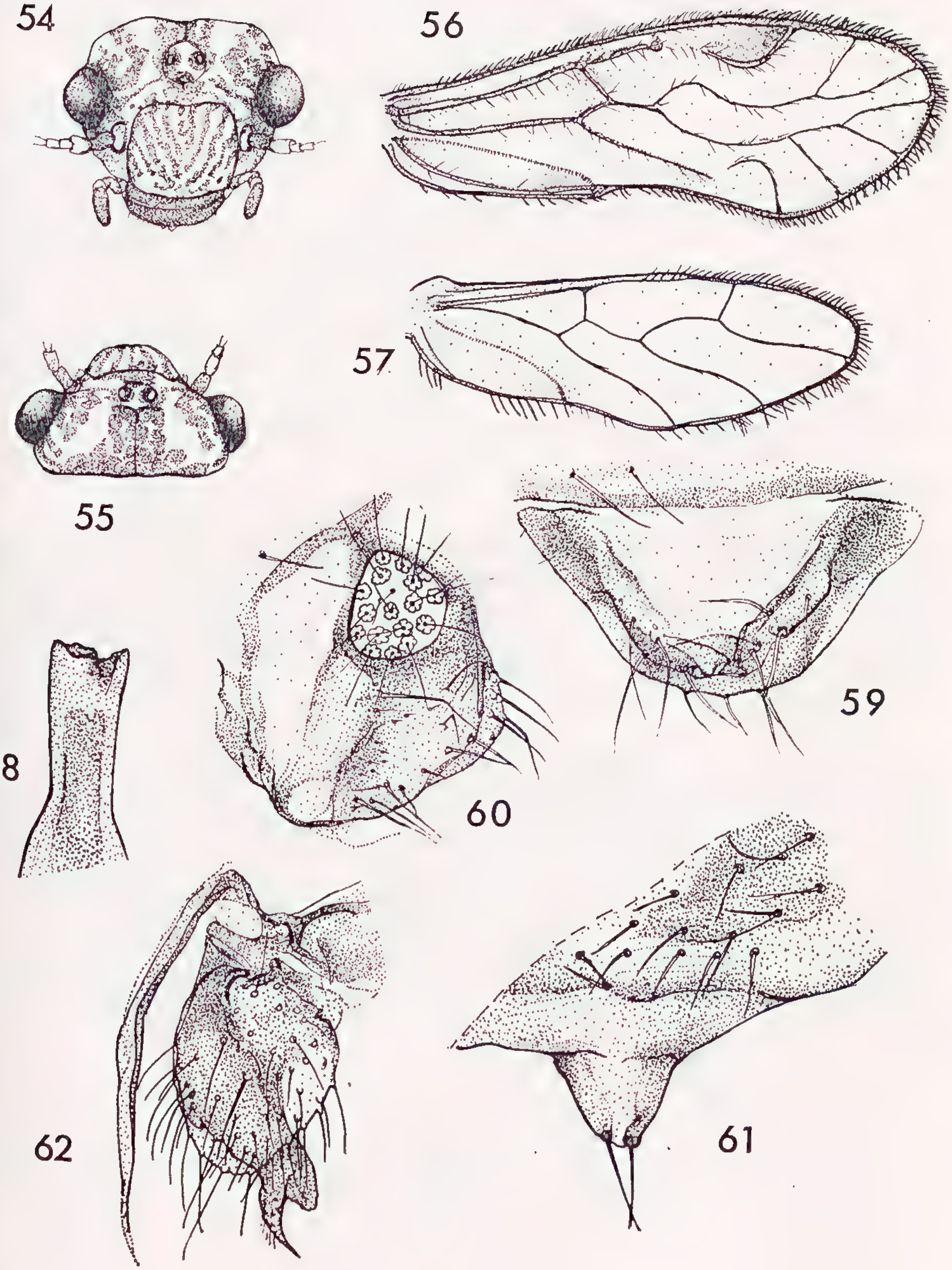
62 61



Figs 54–62. *Haplophallus emmus* sp. n. 54, ♀ head-front; 55, ♀ head; 56, ♀ fore wing; 57, ♀ hind wing; 58, ♀ lacinia; 59, ♀ epiproct; 60, ♀ paraproct; 61, ♀ subgenital plate; 62, ♀ gonapophyses.

figure (56). Hind wing (fig. 57) with faint fuscous areas in anal angles. Basal two abdominal terga largely white, terga 3–5 largely granular brown, 6–9 largely white with brown granulation on anterior and posterior margins and two dark longitudinal streaks dorsally. Sterna uniform brown.

Morphology.—Body length: 2.50 mm. IO/D: 3.33. Median epicranial suture distinct. Length of flagellar segments: f_1: 0.378 mm; f_2: 0.275 mm; f_1:f_2: 1.375. Anterior ocellus much smaller than lateral ocelli. Lacinial apex as in figure 58. Measurements of hind leg: F: 0.480 mm; T: 0.992 mm; t_1: 0.330 mm; t_2: 0.050 mm; t_3: 0.066 mm; rt: 6.60:1:1.32; ct: 15, 0, 0. Fore wing length: 3.18 mm; fore wing width: 1.15 mm. Fore wing with costa fairly thick beyond distal section of subcosta, *rs* long, curving strongly before forking. Hind wing length: 2.41 mm; hind wing width: 0.48 mm. Setae on hind wing veins: r_1: 6, *rs:* 0, r_{2+3}: 0; r_{4+5}: 12, *m:* 10, cu_1: 8. Epiproct (fig. 59) rounded apically, with scattered setae. Paraproct (fig. 60) simple, with circular field of 18 trichobothria, 2 not in rosette sockets. Subgenital plate as in figure 61, number of apical seta varies. Gonapophyses as in figure 62, dorsal valve with sharp curved subapical spine bearing a group of short fine setae subapically, outer valve oval with long setae.

MALE

Coloration (freshly killed, in alcohol).—As female, with following exceptions: pterostigma pigment more extensive, almost filling pterostigma (fig. 63); hind wing (fig. 64); all markings except those along vertex-frons suture darker than in female; femoral bands merge completely in hind leg; abdominal terga 1–5 with extensive brown granulation, terga 6–8 largely white, brown granulation on anterior and posterior margins, two dark longitudinal streaks along abdomen dorsally and an additional longitudinal mark each side over terga 1–5. Ninth tergite, hypandrium (fig. 65) and paraprocts (fig. 66) dark brown, epiproct and trichobothrial fields white.

Morphology.—Body length: 2.25 mm. Lengths of flagellar segments: f_1: 0.515 mm; f_2: 0.305 mm; f_1:f_2: 1.689. Antennae thicker than in female, eyes a little larger than in female. IO/D: 2.5. Anterior ocellus smaller than lateral. Measurements of hind leg: F: 0.515 mm; T: 1.096 mm; t_1: 0.330 mm; t_2: 0.045 mm; t_3: 0.066 mm; rt: 7.33:1:1.47; ct: 16, 0, 0. Fore wing length: 3.16 mm; fore wing width: 1.16 mm. Fore wing morphology as female. Hind wing length: 2.39 mm; hind wing width: 0.51 mm. Setae on hind wing veins as follows: r_1: 7, *rs:* 3, r_{2+3}: 0, r_{4+5}: 14, *m:* 12, cu_1: 8. Epiproct rounded apically, setose near apical margin. Paraproct with circular field of 24 trichobothria, 2 not in rosette sockets, hind margin of paraproct thickened. Hypandrium (fig. 65) simple. Phallosome (fig. 67).

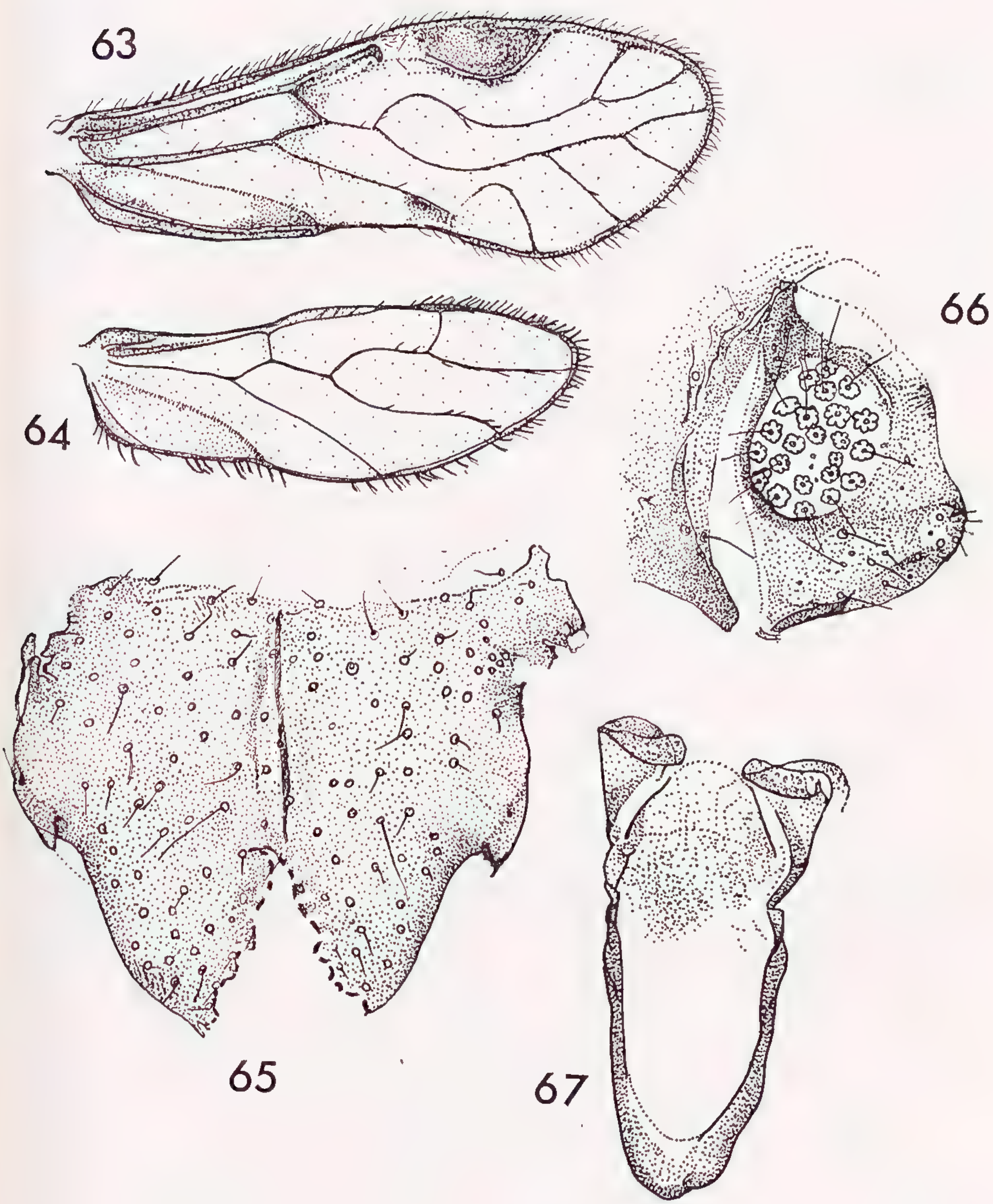
MATERIAL EXAMINED

Norfolk Island: 1 ♀ (holotype) Captain Cook Monument, 31.viii.1971; 1 ♂ (allotype) Mount Pitt, 2.ix.1971 (C. N. Smithers and I. W. B. Thornton); 1 ♀ Mount Pitt, 3.iii.1969 (C. N. Smithers); 2 ♀ Ross Point, 24.xi.1968 (A. S. Smithers); 2 ♀ Rocky Point Reserve, 23.xi.1968 (C. N. Smithers).

Holotype, allotype, and paratypes in Australian Museum.

DISCUSSION

H. emmus belongs to a group of philotarsids in which the hind wing veins are setose, cu_2 in the fore wing is bare, the antennal segments lack white apices and the fore wing setae are not sited on dark spots, veins *rs* and r_{2+3} in the hind wing are



Figs 63–67. *Haplophallus emmus* sp. n. 63, ♂ fore wing; 64, ♂ hind wing; 65, ♂ hypandrium; 66, ♂ paraproct; 67, ♂ phallosome.

bare or carry only very few setae, and the phallosome is simple. This group includes *Haplophallus orientalis* Thornton, the type species of *Haplophallus*, found in Hong Kong and Ceylon, *H. fenestristigma* (Enderlein) from the Seychelles, *H. basilewskyi* (Smithers) from Tanganyika, *H. maculatus* (Tillyard) from New Zealand, *H. fuscistigma* Thornton *et al.* and *H. boninensis* Thornton *et al.* from Micronesia, and a species yet to be described, found in New Caledonia, Fiji, and Samoa. *H. emmus* is most similar to the last species mentioned above, but differs in the following features: fore wing without brown clouds in apical cells, dorsal valve of female gonapophyses with subapical projection sharply pointed, outer valve not so nearly circular, female subgenital plate with only two apical setae. The male genitalia are extremely similar, the outer parameres being somewhat wider apically in *H. emmus*. It seems very likely that *H. emmus* and the New Caledonian species have a close phylogenetic relationship, the latter species having a wider range and thus possibly being the older. *H. emmus* could have diverged from the ancestral form as a result of its isolation on the small island of Norfolk.

PSOCIDAE

Blaste lignicola (Enderlein)

MATERIAL EXAMINED

Norfolk Island: 4 ♂, 14 ♀, Ross Point, 24.xi.1968; 2 ♂, 7 ♀, Melanesian Mission, 20.xi.1968 (A. S. Smithers); 1 ♀, Mt Pitt, 19.xi.1968 (G. F. Smithers); 3 ♂, 9 ♀, Bumbora, 31.viii.1968 (C. N. and A. S. Smithers); 3 ♂, 10 ♀, Ross Point, 27.xi.1968; 3 ♂, 1 ♀, Rocky Point Reserve, 23.xi.1968; 1 ♂, Palm Glen, 24.xi.1968 (C. N. Smithers); 1 ♂, Middlegate, xii.1968 (N. L. H. Krauss); 4 ♀, Ross Point, 31.viii.1971; 1 ♀, Rocky Point Reserve, 28.viii.1971; 3 ♂, Selwyn Pine Rd, 31.viii.1971 (C. N. Smithers and I. W. B. Thornton).

This species is known from eastern Australia.

ACKNOWLEDGMENTS

We would like to thank the Australian Research Grants Committee and the Trustees of the Australian Museum for financial support enabling the authors to undertake field work on Norfolk Island, Dr S. K. Wong for providing New Zealand material for comparison and Miss J. O'Regan for preparing the illustrations to this paper. We would like to thank Mrs Aletta Smithers for collecting much of the material mentioned.

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Footnote: Since this paper was written, two females of *Phlotodes griseipennis* (McL.), a common Australian species, have been taken at Point Blackbourne and Cascade, 17–23.iii.1974, by Mr and Mrs F. Jowett.

Cymodetta gambosa, a New Sphaeromatid Isopod (Crustacea) from Australia, with Notes on its Mating Behaviour

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Plate 8. Figures 1–27. Manuscript received 23rd November, 1973

SUMMARY

Cymodetta gambosa, a new genus and species of the isopod family Sphaeromatidae, is described from specimens in a culture derived from the Clarence River at South Grafton, New South Wales, Australia. The new genus belongs to Hansen's Hemibranchiatae, and apparently to his section Sphaeromini, but in contrast to known genera of Sphaeromini has uniramous uropods. The 5th pereopods exhibit a striking sexual dimorphism; in the male the propus is expanded into a prominent lobe overriding the dactyl. Mating behaviour is described, including the function of the propal lobe in preventing the female from rolling up.

INTRODUCTION

The isopod described herein is one of several species that was collected from wood in Australian waters and maintained in culture in the Bundesanstalt für Materialprüfung (BAM) in Berlin. It was originally incorrectly assigned to the genus *Cilicaeopsis* by Kühne (1973). It is noteworthy not only because it represents a

new species in a new genus of uncertain affinities among the hemibranchiate Sphaeromatidae, but also because of the unusual sexual dimorphism, especially in the 5th pereopods. We felt confident that the conspicuous process of the propus of the male 5th pereopod must have a role during mating. Our belief was confirmed by observations of the mating behaviour made at the BAM, an account of which follows the description of the new isopod.

TAXONOMY

Cymodetta, new genus

A member of the hemibranchiate group of Sphaeromatidae; pleopods 4 and 5 with bimerous membranous exopods and with undivided fleshy endopods, the latter with fewer transverse folds than in most Hemibranchiatae. Pleotelson pointed apically; apical part solid below, without a notch or longitudinal excavation. Pereon, pleon, and pleotelson without dorsal processes in either sex. Uropods with narrow exopods; endopods lacking in both sexes. Mouth-parts normal in female. Pereopods slender, without long setae; propus of male pereopod 5 produced into broad lobe overriding dactyl. Male pleopod 2 with complex stylet. Oostegites small, on pereonites 2–5. Penes well developed, separate to base.

Etymology

The name is derived by adding the diminutive suffix "etta" to the first part of the sphaeromatid generic name *Cymodoce*. Gender, feminine.

Type-species

Cymodetta gambosa, new species.

Relationships

Cymodetta is clearly a hemibranchiate and appears to belong to Hansen's (1905) section Sphaeromini rather than to his section Cymodocini. In the Cymodocini the telson is notched apically and the mouthparts of the adult female are reduced. *Cymodetta* differs from other genera of Sphaeromini in having uniramous uropods. Among the Hemibranchiatae the males of *Cilicaeopsis* and *Paracilicaea* (both Cymodocini) have short or rudimentary endopods, but in other genera both rami are usually well developed.

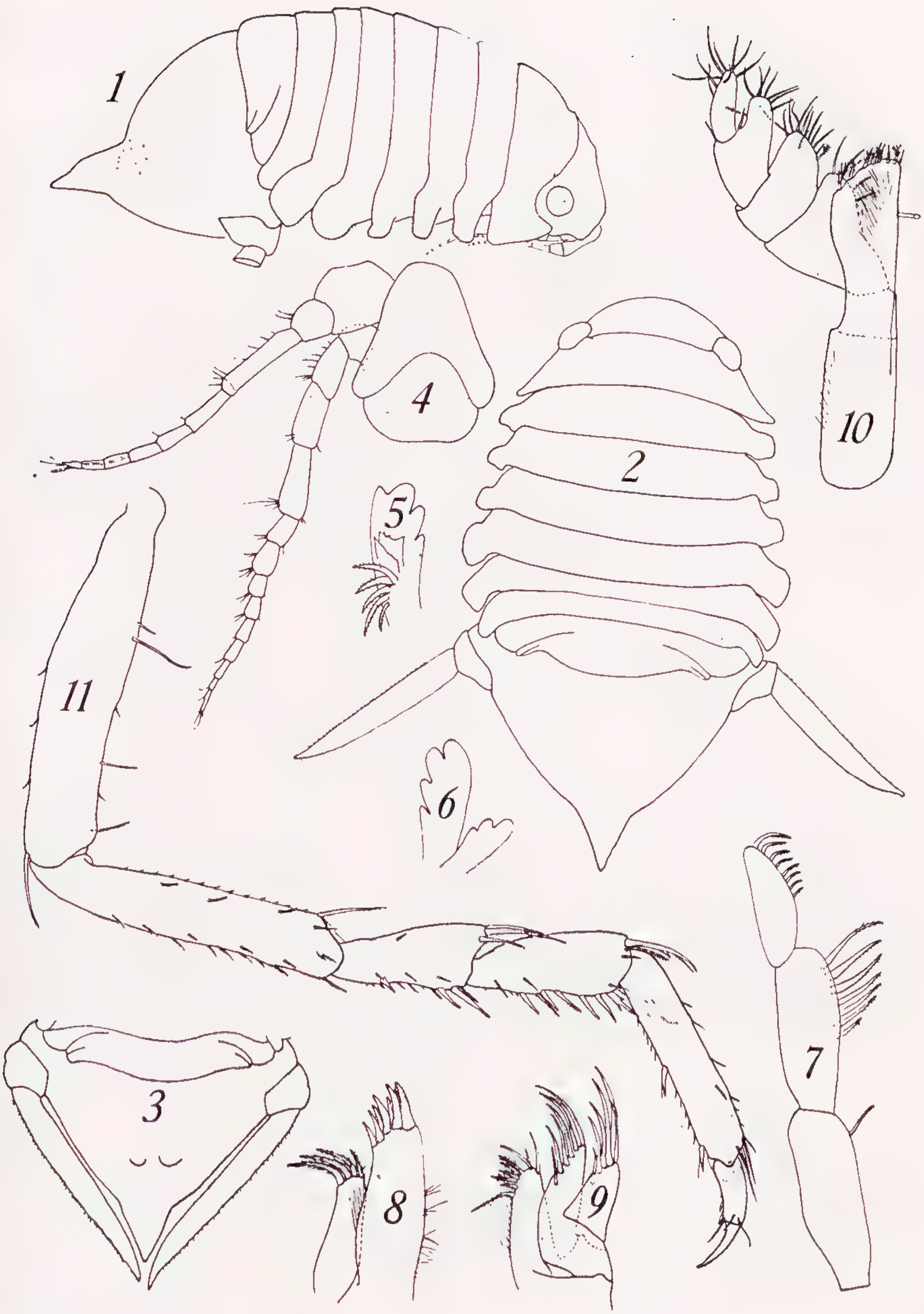
Cymodetta gambosa new species

Figures 1–27, Plate 1

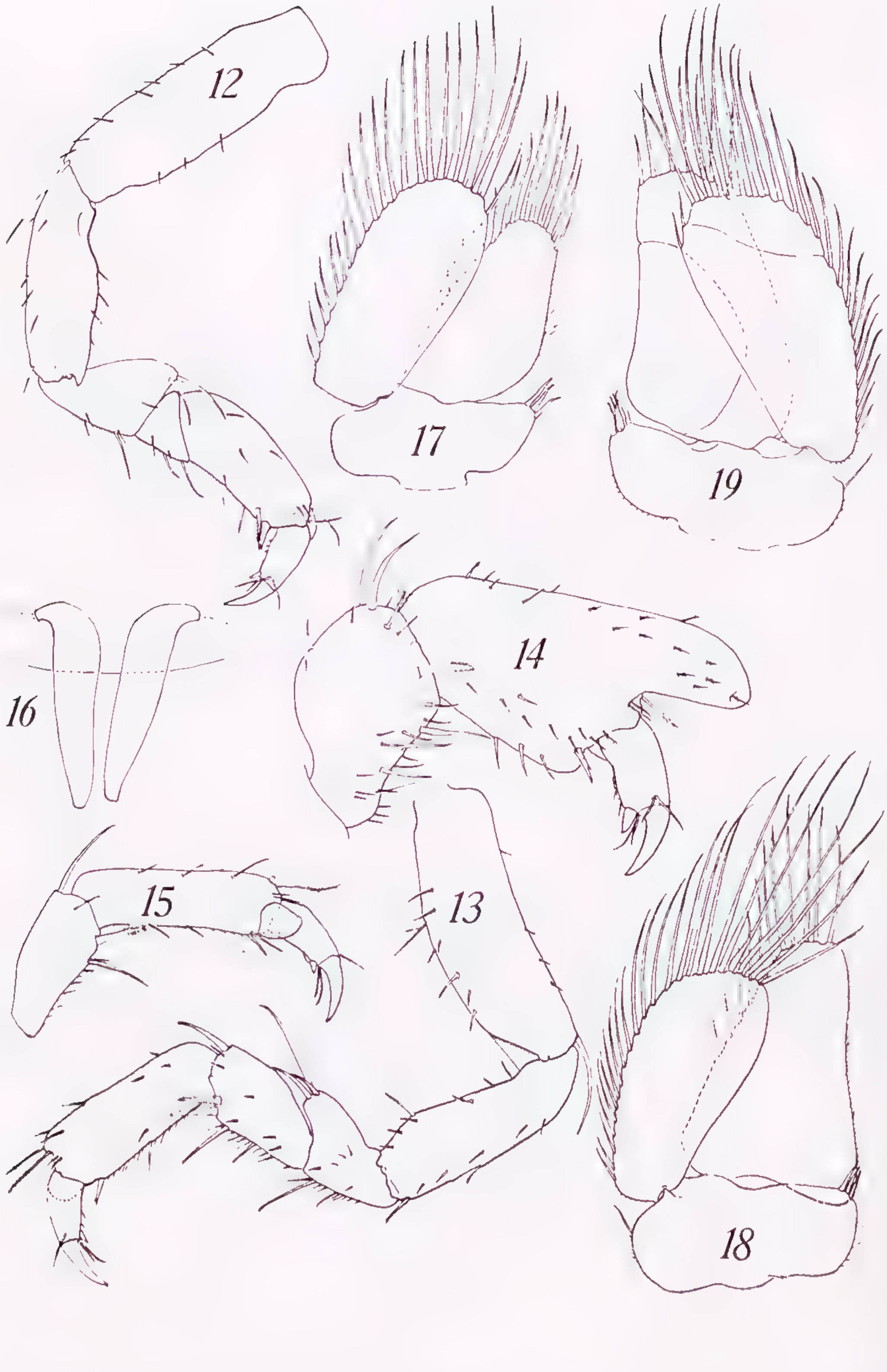
Cilicaeopsis sp. Kühne, 1973: 816, table 2, fig. 9.

Description

Body rather flat, about 1.7 times as long as wide. Pereonite 1 about as long as head, with transverse depression behind posterior margin of head. Pereonites gradually widening posteriorly, greatest width at pereonite 5; pereonites 6 and 7 narrower; anterior epimera narrow, separated by distinct gaps; posterior epimera



Figures 1–11. *Cymodetta gambosa.* Fig. 1, ♂ lateral; fig. 2, ♂ dorsal; fig. 3, ♀ pleotelson, dorsal; fig. 4, ♀ labrum, clypeus, antenna 1 and 2, ventral; fig. 5, ♂ right mandible, incisor and spine row; fig. 6, ♂ left mandible, incisor and lacinia; fig. 7, ♂ mandibular palp; fig. 8, ♂ maxilla 1; fig. 9, ♂ maxilla 2; fig. 10, ♂ maxilliped; fig. 11, ♂ left pereopod 7.



Figures 12–19. *Cymodetta gambosa.* Fig. 12, pereopod 1, 3 mm ♂; fig. 13, pereopod 5, 3 mm ♂; fig. 14, distal segments of pereopod 5, 4 mm ♂; fig. 15, same, ♀; fig. 16, penes; fig. 17, left pleopod 1, 3 mm ♂; fig. 18, left pleopod 2, 3 mm ♂; fig. 19, right pleopod 3, 3 mm ♂.

broader, overlapping. Pleonal sutures indistinct, separate. Pleotelson triangular; anterior 2/3 hemispherical, vaulted, smooth in male, with a pair of low, submedian bosses in female; posterior third abruptly narrowed, with acute apex.

Antenna 1, 1st segment of peduncle broad, twice as long as 2nd; 3rd article slender, its length subequal to 1st, flagellum 6-segmented. Antenna 2 longer than antenna 1; flagellum 9-segmented. Mandible with flat molar having grinding ridges on surface, ridges more prominent on molar of left mandible; incisor ending in 4 rounded cusps, lacinia with 3 cusps; palp with subequal 1st and 2nd segments, 3rd segment about 1/3 shorter. Maxilla 1 with 9 apical spines on exopod and 4 more slender spines on endopod. Segments of maxilliped palp rather sparsely armed; inner lobes only moderately developed. Pereopods slender, not heavily spinose; pereopod 5 of adult male with propus produced posterodistally into oblong process; pereopods 6 and especially 7 distinctly longer than other pereopods. Pleopod 2 of adult male with stylet curving gently laterally, reaching slightly beyond endopod; distal fourth folded back on its posterior surface, ending in several complex fleshy setose lobes. Pleopod 3 endopod with suture parallel to lateral margin. Pleopod 4 with a few rudimentary transverse folds in proximal part of both rami, undeveloped in immature specimens. Pleopod 5 exopod with rather low squamiferous protuberances; endopod with shallow and irregularly arranged folds in adult, folds not developed in immature specimens.

Etymology

The specific name is from the Latin "gambosus", = "having a swelling near the hoof", and refers to the modified propus of the male pereopod 5.

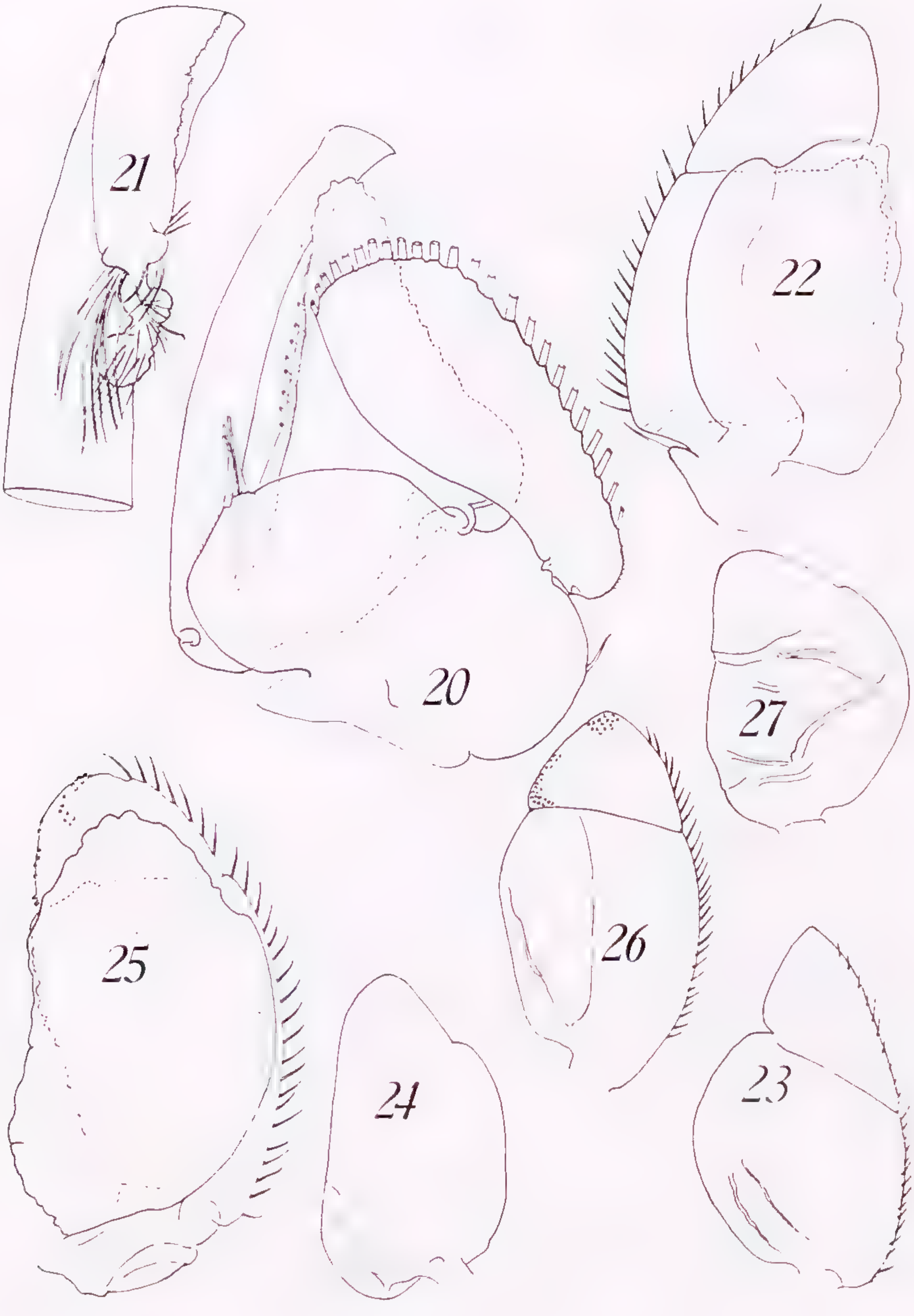
Types

Male holotype, total length (from anterior margin of head to posterior margin of telson) 4.0 mm, USNM 142255; female allotype, 3.6 mm, USNM 143982, and 100+ paratypes, USNM 143983 are deposited in the Division of Crustacea, Smithsonian Institution. Additional paratypes have been deposited in the Australian Museum, Sydney, and the Zoologisches Museum, Berlin. All specimens were from cultures maintained at the BAM, derived from a collection from submerged wood made by Rosalie Keirle (Wood Technology Division, Forestry Commission of New South Wales, Beecroft) in the Clarence River at South Grafton, New South Wales, Australia, 14th September 1971.

Distribution

After we had completed a draft of this manuscript, we learned from Dr Donald F. Boesch, Virginia Institute of Marine Science, that he had collected specimens of our new sphaeromatid from several localities along the eastern coast of Australia and had independently judged it to represent a new genus and species. Dr Boesch generously deposited specimens in the Smithsonian Institution and has permitted us to cite his collection data.

Dr Boesch's data show that *Cymodetta* inhabits fresh or brackish water (0–20‰ north to the Burran River, Howard, Queensland, and south at least to the East Gippsland lakes in Victoria). It occurs on various types of bottoms: among littoral weeds, on mud, sand, stones, and rocky bottoms. It is quite tolerant of fresh water



Figures 20–27. *Cymodetta gambosa.* Fig. 20, pleopod 2, anterior, 4 mm ♂; fig. 21, detail of apex of stylet of same, posterior; fig. 22, right pleopod 4, 3 mm ♂; fig. 23, right pleopod 4, exopod, 4 mm ♂; fig. 24, endopod of same; fig. 25, left pleopod 5, 3 mm ♂; fig. 26, left pleopod 5, exopod, 4 mm ♂; fig. 27, endopod of same.

and is common in Lake Barracoota, a freshwater lake in Victoria that was isolated recently from Mallacoota Inlet by sedimentation (Timms, 1973) as well as in "blind estuaries" temporarily isolated from the sea for several months. *C. gambosa* is the "unidentified sphaeromid isopod" listed by Timms, who points out that two other species of marine origin also survive today in Lake Barracoota, an anthurid isopod and a spionid polychete, both undescribed.

Mating Behaviour

Specimens were cultured individually in petri dishes 6 cm in diameter in water with a salinity of 20% at 22°C. The food provided consisted of sections of pine sapwood, 20 x 10 x 1 mm, which had been stored in sea water for one year, and sufficient unicellular algae (*Dunaliella* sp.) to make the water slightly cloudy. Twice a week, during a period of 4 weeks, pairs were placed together and observed with a stereoscopic microscope and photographed.

When a pair of isopods comes into contact, the male grasps the female with his pereopods. The female responds by rolling together, either firmly or loosely depending on her readiness to copulate. The male turns the female around several times and often taps her by suddenly bending his head and uropods. If the female is not ready and remains firmly rolled up, the male usually releases her very soon. If the female is receptive and only loosely rolled together, the male turns her until his ventral side faces her lateral side. Usually the male uses pereopods 1–4 to cling to the lateral side of the pereon of the female and the longer pereopods 6–7 to grasp the dorsal side of the pleotelson. The male then prods the ventrolateral side of the female several times with his pereopod 5 nearest to her. During copulation the male pereopod 5 pushes against the ventral surface of the female; the propal process is appressed and the dactyl is splayed from it. The male pleopods 1 and 2 are bent forward in the shape of a funnel, while the posterior pleopods continue their rhythmic beat. Presumably the sperm is released at this time. The male may shift to the opposite side of the female, in which case the opposite pereopod 5 is used as described. Mating may last for more than 1 hour.

Males will attempt to copulate with females regardless of the moulting condition of the latter. On one occasion a male attempted to copulate with another male.

It is not clear whether the male's prodding with pereopod 5 before copulation serves as a stimulus to the female or aids the male in finding the most effective position for pereopod 5 during copulation. It is clear that pereopod 5 aids in preventing the female from rolling up, and the propal process is an adaptation for this function.

The dimorphism of the pleotelson is unusual; in most Sphaeromatidae ornamentation is greater in the male, but the reverse is true in *C. gambosa*. Possibly the dorsal bosses of the female facilitate the male's clinging to her during copulation.

Sexual dimorphism is often well developed, sometimes markedly so, in the Sphaeromatidae, but the modified pereopod 5 of *C. gambosa* and its function in mating described herein has no parallel among the Sphaeromatidae of which we are aware. Published accounts of mating behaviour in the Sphaeromatidae are rare, but information is available for *Cassidinopsis maculata* (Studer, 1884) and for *Ancinus*.

Among 15 preserved specimens of *C. maculata* from the Kerguelen Islands, Monod (1930) found 3 pairs in copula. The much larger male held the smaller female with her dorsum fitting into his somewhat concave ventral surface. The male pereopod 4 with its long, slender, twisted basis, holds the female in place; pereopods 1–3 have setae or spines missing in the female, and Monod suggests that they may also play a role during mating. In *Ancinus* the smaller female is also carried below the larger male, but in this case she is held in position by the modified male pereopod 2 which is subchelate rather than ambulatory as in the female (Glynn and Glynn, in press).

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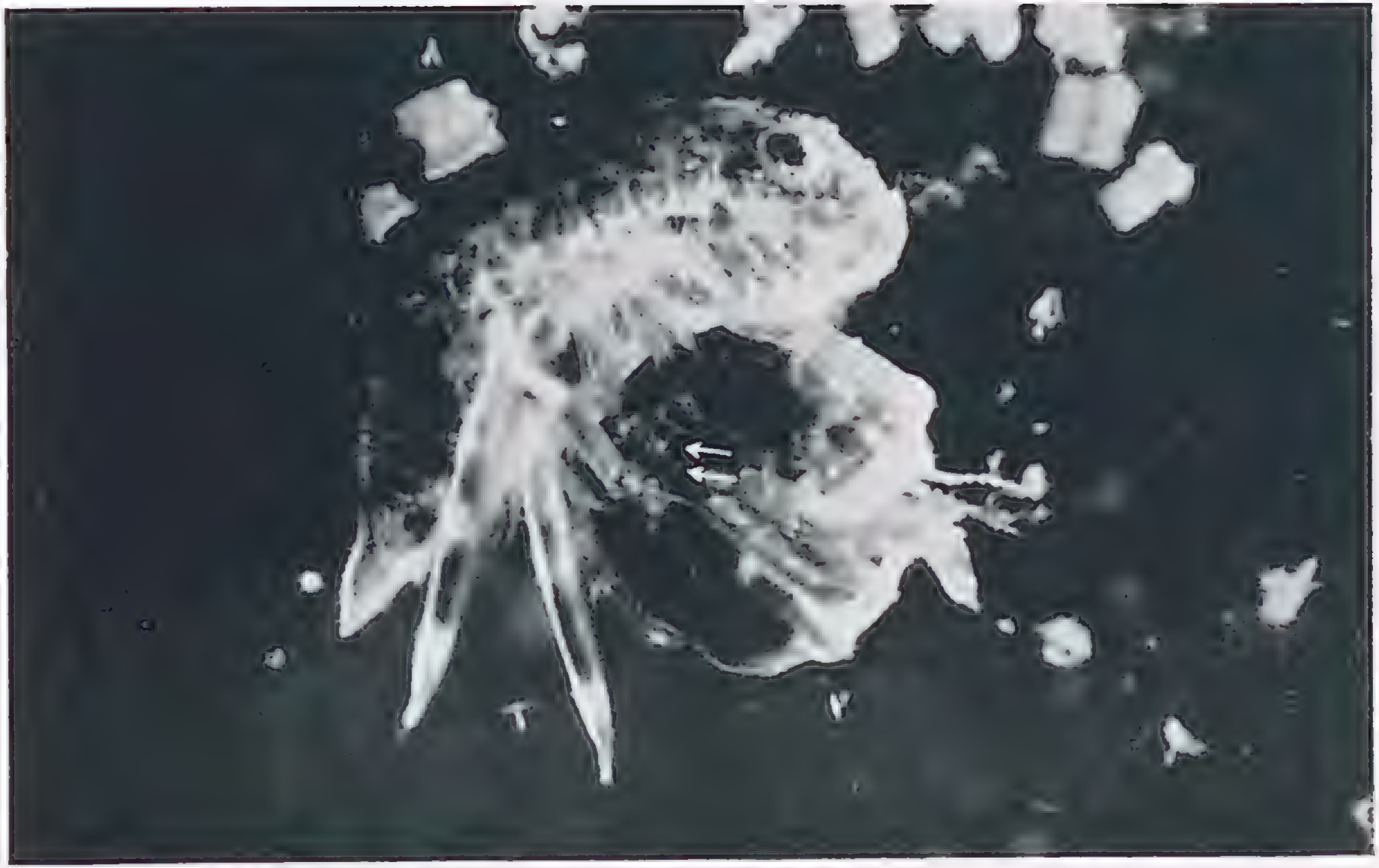

Plate 8. *Cymodetta gambosa.* ♂ (above) and ♀ in copula. Arrows point to propal process and dactyl of ♂ pereopod 5.

THE EARTHWORM GENUS *OREOSCOLEX* (OLIGOCHAETA: MEGASCOLECIDAE) IN NEW SOUTH WALES

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Figures 1–3 Manuscript received 22nd August, 1973, revised 15th February, 1974

SUMMARY

Descriptions are given of four species of *Oreoscolex* recently transferred to this genus from *Notoscolex*. All are shown to have the eight setae per segment and multiple caudal nephrostomes diagnostic of the genus. A key to the five species of *Oreoscolex* in New South Wales, including the type-species *O. imparicystis*, is given. Occurrence of a further eight species in Tasmania strongly suggests that the genus will also be found in intervening Victoria.

INTRODUCTION

The genus *Oreoscolex* was erected by Jamieson (1973) for a hitherto unknown species, from Mt Kosciusko, which formerly would have been assignable to *Notoscolex*. *Oreoscolex* was distinguished by the presence of multiple caudal nephrostomes (a feature of the Tribe Magascolecini) from *Notoscolex*, in which only the medianmost meronephridium on each side in the caudal region was stomate. The latter condition, where nephridia discharged to the exterior, had been shown (Jamieson, 1971a) to diagnose a tribe Dichogastrini.

Since *Oreoscolex* was erected, eight Tasmanian species and four species from New South Wales have been added to the genus (Jamieson, 1974). Whereas four of the Tasmanian species were new, those from New South Wales were known species originally referred by Fletcher (1887a, b; 1889a, b) to *Cryptodrilus* and *Notoscolex* and placed by Michaelsen (1900) in the latter genus.

The present account provides more exhaustive descriptions of the four additional species from New South Wales than were given by Fletcher and justifies assigning them to *Oreoscolex*. All of the material described is in the collections of the Australian Museum, Sydney.

The terminology employed is that normally used in oligochaete taxonomy. Explanations of it are available in Michaelsen (1900) and Jamieson (1971a, 1974).

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SYSTEMATICS

Genus **Oreoscolex** Jamieson, 1973

Diagnosis:

Setae 8 per segment. A pair of combined pores of vasa deferentia and racemose or tubuloracemose prostates on XVIII. Gizzard in V. Extramural calciferous glands and typhlosole present or absent. Meronephric, anterior nephridia astomate, avesiculate, exonephric or enteronephric, and usually tufted. Caudal nephridia with numerous preseptal funnels on each side in each segment, exonephric (or enteronephric?). Spermathecae in 2 or 3 segments, paired or median; diverticula uniloculate or multiloculate.

Distribution:

Eastern Subregion of Australia: New South Wales and Tasmania. (13 species).

Type-species:

Oreoscolex imparicystis Jamieson, 1973a.

NEW SOUTH WALES SPECIES

1. *Notoscolex grandis* Fletcher, 1887a
2. *Cryptodrilus illawarrae* Fletcher, 1889a
3. *Oreoscolex imparicystis* Jamieson, 1973a
4. *Cryptodrilus saccarius* Fletcher, 1887b
5. *Cryptodrilus simulans* Fletcher, 1889b

Remarks:

The four species listed above in addition to the type-species were not included in the amended generic definition (Jamieson, 1974), but they necessitate no further amendment of the definition beyond deletion of parenthetical references to individual species-names, omission of 'rarely' from the allusion to occurrence of seminal vesicles in XI and XII, and inclusion of the observation by Fletcher (1887b) for *C. saccarius*, of intestinal origin in XV which is not, however, confirmed in the present study.. Only the brief generic diagnosis is therefore repeated above.

To allow comparison of New South Wales species with the remaining (Tasmanian) species of the genus the following key includes all known species of the genus.

Key to the Species of **Oreoscolex**

1. Spermathecal pores unpaired, midventral, posteriorly in VII and VIII. ......*O. imparicystis* Jamieson, 1973. N.S.W.

— Spermathecal pores 2 or 3 pairs, in or near 6/7–8/9 2

2. (1) Spermathecal pores 2 pairs, in or immediately behind 7/8 and 8/9 ... 3

— Spermathecal pores 3 pairs in 6/7, 7/8 and 8/9. .... *O. sexthecatus* Jamieson, 1974. Tas.

3. (2) Spermathecae each with 2 separate subspherical to clavate diverticula 4

— Spermathecae each with a single uniloculate or multiloculate diverticulum 5

4. (3) A pair of reniform calciferous glands in each of XV and XVI.

.... *O. bidiverticulatus* Jamieson, 1974 (part). Tas.

— Extramural calciferous glands absent.

.... *O. illawarrae* (Fletcher, 1889a). N.S.W.

5. (3) Spermathecal diverticulum uniloculate 6

— Spermathecal diverticulum multiloculate 9

6. (5) Male pores in *ab* on XVIII.................................... 7

— Male pores median to *a* on XVIII 8

7. (6) A pair of reniform calciferous glands in each of XV and XVI.

.... *O. bidiverticulatus* Jamieson, 1974 (part). Tas.

— Extramural califerous glands absent.... *O. longus* Jamieson, 1974. Tas.

8. (6) Male pores almost contiguous medianly, on a circular porophore median to *b* lines. A median genital marking in 20/21.

.... *O. irregularis* (Spencer, 1895). Tas.

Male pores shortly median to *a* lines on a transverse porophore which extends lateral of *b* lines and impinges on adjacent segments.

.... *O. peculiaris* Jamieson, 1974. Tas.

9. (5) Oesophagus vascularized, and sometimes with internal lamellae, but lacking extramural calciferous glands 10

— Oesophagus with pairs of dorsolateral calciferous glands 13

10. (9) Penial setae present 11

— Penial setae absent. .... *O. grandis* (Fletcher, 1887a). N.S.W.

11. (10) Eyelike or other paired genital markings absent................. 12

— A pair of eyelike genital markings present in *ab* in 17/18 or XVII and in each of several intersegments behind XVII.

.... *O. campestris* (Spencer, 1895). Tas.

12. (11) A large median transverse genital marking in each of intersegments 15/16–18/19, extending approximately to *b* lines.

.... *O. leai* (Michaelsen, 1910). Tas.

— A large midventral glandular pad in 19/20 or 20/21 extending laterally beyond *b* lines. .... *O. wellingtonensis* (Spencer, 1895). Tas.

13. (9) Calciferous glands in VIII, or IX, to XIII. Last hearts in XIII.

.... *O. saccarius* (Fletcher, 1887b). N.S.W.

— Calciferous glands in XIII, or XIV, to XV. Last hearts in XII.

.... *O. simulans* (Fletcher, 1889b). N.S.W.

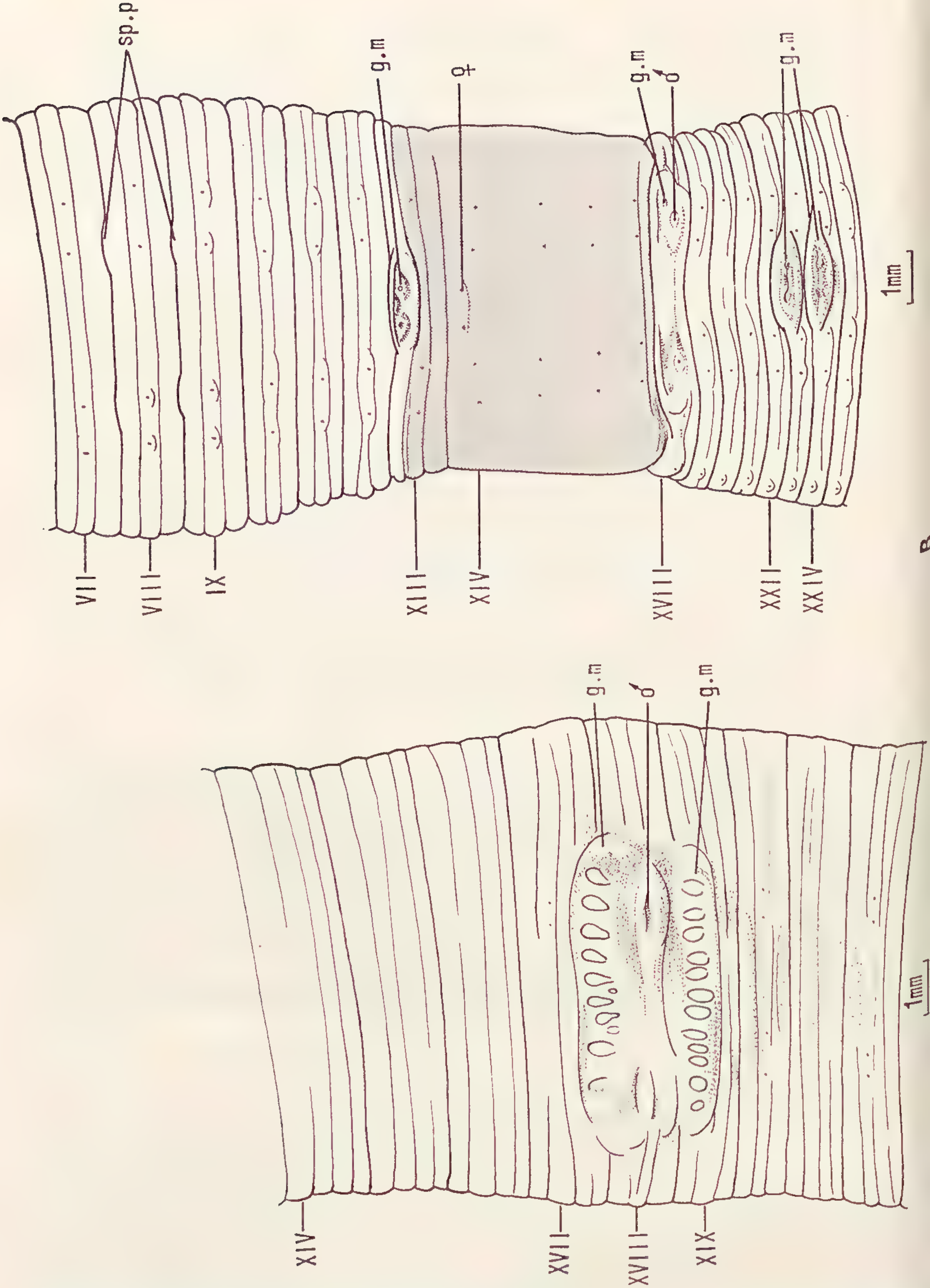

Figure 1.—Male genital field of A, *Oreoscolex grandis*, sexual specimen, W.1491; B, *O. saccarius*, W.1372 (1). Abbreviations: ♀ female pore; g.m. accessory genital marking; ♂ male pore. Roman numerals are segment numbers. Clitellum shaded. All figures drawn by camera lucida.

Oreoscolex grandis (Fletcher, 1887a)

Figs 1A; 3A

Notoscolex grandis Fletcher, 1887a: 551–554, pl. VIII, fig. 6.—Michaelsen, 1900: 190–191.—Jamieson, 1971b: 78.

Megascolides grandis.—Beddard, 1895: 448.

Cryptodrilus grandis.—Beddard, 1895: 505.

Oreoscolex grandis.—Jamieson, 1974: 303.

Description:

l = 570–760 mm, w = 10–11 mm, s?*. Prostomium prolobous to pro-epilobous; peristomium with numerous longitudinal grooves. First dorsal pore 10/11. Setae minute, only very sporadically visible (eight per segment); ventral setal couples closely paired; dorsal couples not seen. Nephropores not seen. Clitellum annular, posterior XIII, XIV–XIX; not developed in re-examined specimen. Male pores extensive transverse slits in *ab*, equatorially in XVIII, on a strongly protuberant midventral unpaired pad which extends laterally well beyond *b* lines and fills approximately the posterior and anterior third of segments XVII and XIX respectively; the anterior and posterior portions of the pad have each a transverse row of white glandular very slightly protuberant oval or elliptical markings (re-examination); more frequently the pad is divided into an anterior ridge on the anterior margin of XVIII and a posterior ridge in a similar position on XIX. Female pores on XIV, close together; not visible in re-examined specimen. Spermathecal pores 2 pairs, in 7/8 and 8/9, in *ab*, each surrounded by a conspicuous elliptical lip which is wider in front of the pore.

Last hearts in XIII, at least those in XII and XIII latero-oesophageal. Supra-oesophageal vessel present but well developed only in XII and XIII. Subneural vessel absent. Gizzard large and firmly muscular, in V; oesophagus strongly vascularized in XII–XVI but extramural calciferous glands absent. Intestinal origin $\frac{1}{2}$ XVIII (XVII according to Fletcher); typhlosole, caeca, and muscular thickening absent. Nephridia: very large apparently enteronephric (pharyngeal) tufts paired in III and IV; very dense bands of numerous integumentary micromeronephridia in succeeding segments; caudal nephridia very numerous and with approximately 13 ventrally situated preseptal funnels on each side in each segment (exonephric?). Holandric (funnels slightly iridescent in X and XI); seminal vesicles large, racemose in XI and XII. Metagynous (ovaries much-branched laminae); ovisacs in XIV. Prostates tongue-shaped, deeply incised in places, the short external duct continuous axially far into the gland but giving off only slightly thinner lateral branches with definite epithelium. Penial setae absent. Spermathecae 2 pairs, ampulla elongate, sessile, with ectal multiloculate diverticulum.

Type-locality:

Burrawang. New South Wales.

Material examined:

"Cotypes", Australian Museum W.1494: fragments, several juveniles and one sexual but aclitellate specimen which was used for the above account.

* l = length, w = maximum width, s = number of segments.

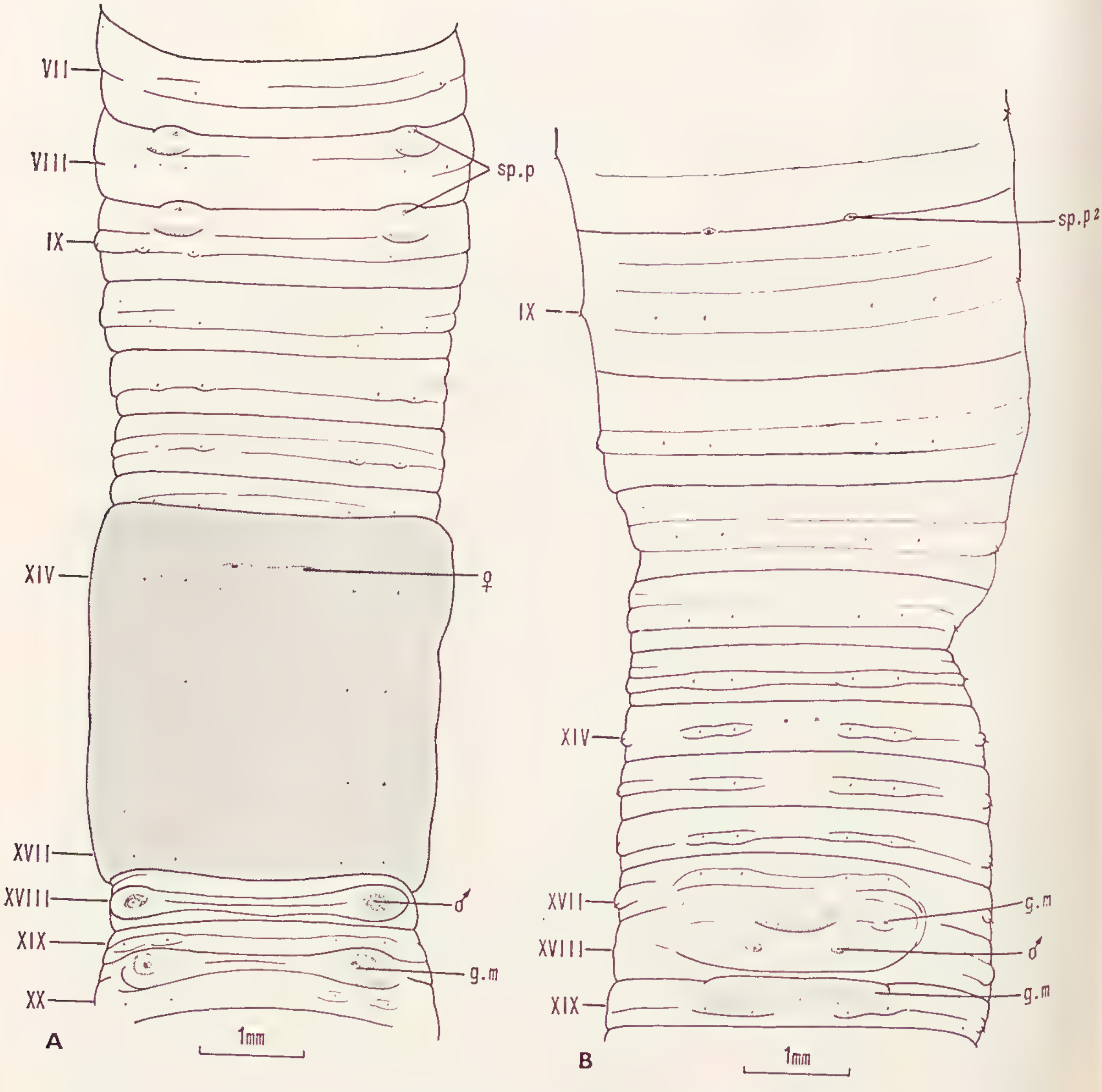

Figure 2.—Male genital field of A, *Oreoscolex illawarrae*, W.1311 (1); B, *O. simulans*, W.1499 (1). Explanation as for figure 1.

Oreoscolex illawarrae (Fletcher, 1889a)

Figs 2A, 3B. Table A

Cryptodrilus illawarrae Fletcher, 1889a: 1546–1547.

Cryptodrilus dubius Beddard, 1895: 503 (non *Cryptodrilus dubius* Spencer, 1892: 136).

Notoscolex illawarrae.—Michaelsen, 1900: 194–195.—Jamieson, 1971b: 79.

Oreoscolex illawarrae.—Jamieson, 1974: 303.

Description

l = 80–100 mm, w = 2–3 mm, s = 250–270. Prostomium epilobous $\frac{1}{2}$, narrow, open. First dorsal pore 10/11 or 11/12. Setae 8 per segment in regular longitudinal rows throughout. *a* and *b* absent in XVIII.

Nephropores not visible. Clitellum annular, $\frac{1}{2}$ XIII, XIV–XVII. Male pores slightly median of *b* lines on XVIII on well developed papillae which extend beyond *ab* laterally and ventrally and are medianly conjoined by the setal annulus which is tumid between them. Accessory genital markings a pair of similar papillae, also medianly conjoined, in 19/20 centred at mid *ab* (*See* Remarks). Female pores a pair, widely separated and approximately $\frac{1}{2}$ *aa* apart, anteromedian of setae *a* of XIV. Spermathecal pores 2 pairs, at the anterior margins of VIII and IX, shortly lateral of *a* lines, on low papillae which fill the presetal annulus.

Last hearts in XII; those in X–XII latero-oesophageal, arising from the supra-oesophageal vessel, but connectives from the dorsal vessel not demonstrable. Supra-oesophageal in $\frac{1}{2}$ IX–$\frac{1}{2}$ XIII, well developed. Gizzard large and firm, with anterior rim, in V. Extramural calciferous glands absent. Oesophagus segmentally dilated (moniliform), with circumferential blood vessels and numerous internal lamellae in VII–XIV; narrower in XV. Intestinal origin XVI; typhlosole, muscular thickening and caeca absent. Nephridia meronephric: very dense bands of innumerable spiral loops in VI anteriorly of which the medianmost, in VI at least, form an enteronephric tuft on each side with composite duct joining the pharynx. Succeeding nephridia very numerous exonephric micromeronephridia in lateral bands in each segment; several preseptal funnels observed on each side in caudal segments. Holandric (sperm funnels iridescent in X and XI); gymnorchous; seminal vesicles racemose, in IX and XII. Metagynous; large ovisacs in XIV. Prostates externally racemose and deeply lobulated in XVIII–XIX, XX but single central duct traceable far into the gland (i.e., tubuloracemose); vas deferens joining the muscular duct, which may be straight or sinuous, near the gland. Penial setae absent. Spermathecae 2 pairs, in VIII and IX; ampulla subspherical; duct wide and muscular with 2 inseminated, almost sessile, subspherical diverticula near its ental end.

Type-locality:

Illawarra, New South Wales.

Material examined:

9 clitellate and 2 sexual but aclitellate specimens labelled "*Notoscolex illawarrae*" and "*Crypto. illawarrae* Mt K.", Australian Museum W.1311, apparently the syntypes. Two specimens were closely examined and one of these was dissected.

Table A

INTERSETAL DISTANCES IN SEGMENT XII

Oreoscolex illawarrae

	mm								Standardized as percentage of periphery							
	aa	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*	*aa*	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*
W.1311 (1)	1·76	0·53	1·34	1·11	2·92	1·07	1·34	0·53	16·60	5·05	12·63	10·46	27·43	10·10	12·63	5·05
W.1311 (2)	1·34	0·34	1·03	0·88	2·38	0·88	1·03	0·34	16·27	4·18	12·55	10·69	28·83	10·69	12·55	4·18
Mean	..	..	..	..	..	..	..	..	16·43	4·61	12·59	10·57	28·13	10·39	12·59	4·61
Intervals/*ab*	..	..	..	..	..	..	..	..	3·56	1·00	2·73	2·29	6·10	2·25	2·73	1·00

Remarks:

The above account extends and confirms that of Fletcher but the genital markings are shown to lie in 19/20 and not, as stated by Fletcher, in 18/19.

Oreoscolex saccarius (Fletcher, 1887b)

Figs 1B; 3C. Table B

Cryptodrilus saccarius Fletcher, 1887b: 951–953; 1889a: 1008–1013.—Beddard 1895: 502–503.—Buchanan, 1910: 221–223.—Raff, 1910: 251, Pl. LI, figs 13, 17, 18.

Notoscolex saccarius.—Michaelsen 1900: 189.—Jamieson, 1971b: 79.

Oreoscolex saccarius.—Jamieson, 1974: 303.

Description:

Unless otherwise indicated, where variation occurs, data in parentheses are from the re-examined specimen.

1 = 50–195 mm, w = 3–12 mm, s = 140–290 (Fletcher); (1 = 80 mm, w = 6 mm, s = 168). Prostomium epilobous (closed). First dorsal pore 10/11, 11/12 or 12/13 (11/12). Setae 8 per segment, commencing on II, in some specimens with a supernumerary seta; rows anteriorly regular but always becoming irregular at distances from the posterior end which vary from shortly preclitellar to one fifth of the body length precaudally; irregularity developing first in *d*, then in *c* and further posteriorly in *a* and *b*. (Regular in the fore- and mid-body; irregular further posteriorly). Setae *a* and *b* absent in XVIII. Nephropores not externally visible. Clitellum annular, $\frac{3}{4}$ XIII–XVII. Male pores in *ab*, or shortly lateral of *b* lines, on the lateral parts of the genital field. This field consisting usually of a rather broad but shallow transverse depression bounded by a tumid rim, most thickened just round and a little beyond the ends of the depression which reaches on each side to a little beyond *b* lines, the depression longitudinally narrowed near the midline so as to appear dumb-bell shaped, the small male papillae at the sites of the absent setae *ab*, confluent with the posterior slope of the depression so that the depressed area passes in front of and beyond them; sometimes with a small papilla, or small pit, dorsal of the male papillae. (The pits anterodorsal, presetally and shortly lateral of *b* lines in the re-examined specimen). The male field sometimes convex rather than depressed. 1 to 3 dots or pits sometimes present in the midline anterior to the male pores. Accessory genital markings: at maturity a pair of pits or papillae near the midventral line and in or near intersegments 11/12, 12/13, 18/19, 3 pairs between any two segments from XX–XXIV, and 1 on the ventral surface of XVIII, these markings surrounded by an elliptical transverse barrier which is concave with an enclosing raised rim or is convex; some or all of the accessory genital markings may be absent; (present anteriorly in XIII, XXIII and XXIV in the re-examined specimen). Female pores paired, anteromedian of *a* on XIV. Spermathecal pores 2 pairs in 7/8 and 8/9 on small protuberances, immediately lateral of *a* lines.

Table B

INTERSETAL DISTANCES IN SEGMENT XII

in *Oreoscolex saccarius*

	mm								Standardized to percentage of periphery							
	aa	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*	*aa*	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*
W.1372 (1)..	2·42	0·88	3·00	2·62	5·92	2·30	2·76	0·76	11·71	4·28	14·49	12·63	28·62	11·15	13·38	3·71
W.1372 (2)..	2·61	0·76	2·76	1·69	6·57	1·76	2·61	0·80	13·33	3·92	14·11	8·62	33·52	9·01	13·33	4·11
Mean	..	..	..	..	..	..	..	..	12·52	4·10	14·30	10·62	31·07	10·08	13·35	3·91
Intervals/*ab*	..	..	..	..	..	..	..	..	3·05	1·00	3·48	2·59	7·57	2·45	3·23	0·95

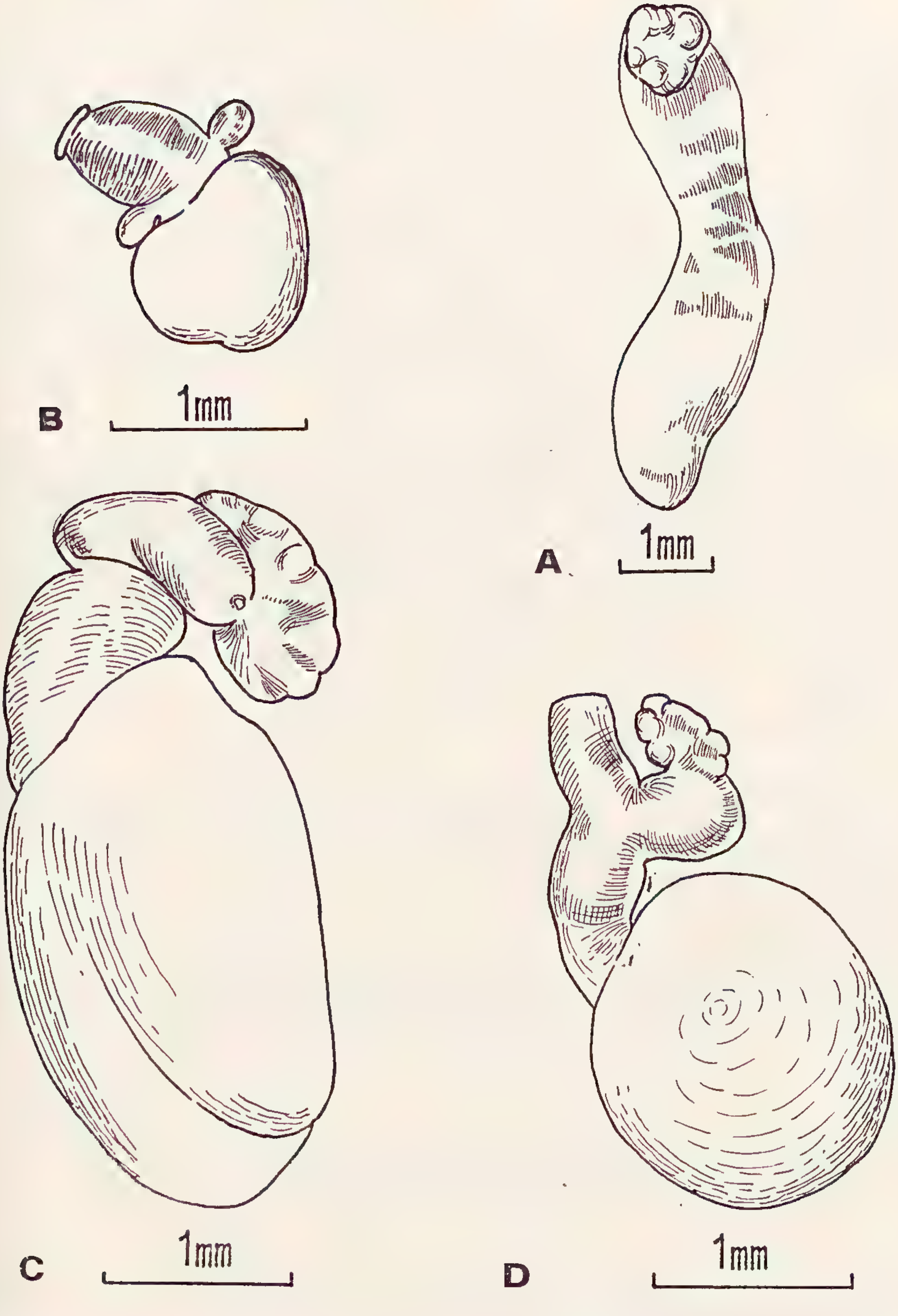

Figure 3.—Spermatheca of A, *Oreoscolex grandis*, W.1494 (1), right VIII; B, *O. illawarrae*, W.1311 (1), right VIII; C, *O. saccarius*, W.1372, (1), right IX; D, *O. simulans*, W.1499 (1), right IX.

Internal anatomy (from re-examined specimen unless otherwise indicated):

Last hearts in XIII (as Fletcher); hearts latero-oesophageal in X–XIII. Supra-oesophageal vessel in X (and further anteriorly?)—XIII, well developed. Gizzard large and firm, in V. Oesophagus with a pair of reniform calciferous glands in each of IX–XIII (VIII–XIII in Springwood specimens, Fletcher 1889a); the glands dorsolateral on the oesophagus with which they communicate by very short but narrow stalks; each gland encircled by a vessel and internally with numerous closely packed radial lamellae. Intestinal origin XVI (XV, Fletcher 1887b; Raff, 1910) typhlosole, muscular thickening and caeca absent. Nephridia: very large tufts in V and VI (salivary glands of Fletcher, 1887b), with innumerable spiral loops in V and VI, those in V at least with composite ducts running forwards to open into the pharynx; smaller, similar tufts in IV; small aggregations of nephridial tubules in II and III, the ducts of which were not traced. In VII posteriorly nephridia forming transverse parietal bands of numerous simple, astomate micromeronephridia. Caudally with numerous exonepheric micromeronephridia, with preseptal funnels, on each side.

Holandric (testes and iridescent funnels in X and XI); gymnorchous; seminal vesicles racemose, in XI and XII (misidentified as testes by Fletcher, 1887b). Metagynous (confirmation); ovisacs in XIV. Prostates racemose and deeply incised, in XVIII and XIX (XIX or XX–XXIV, Fletcher); the duct unusually long and coiled (confirmation); vas deferens joining the junction of duct and gland. Penial setae absent. Spermathecae 2 pairs, in VIII and IX, each with cylindrical to elongate-ovoid ampulla and a longer, narrower, bent or coiled duct with ectal multiloculate (inseminated) diverticulum (confirmation).

Type-locality:

Hornsby (New South Wales).

Other localities:

Eastern portion of County of Cumberland north of Port Jackson (typical form). Springwood, Blue Mountains ("var. montanus"). Near Gosford ("var. robustus"), Fletcher 1889a.

Material examined:

25 sexual and 3 juvenile specimens, with fragments, labelled "*Crypto. saccarius*, Hornsby, Berowra, Manly, King Is., and *Notoscolex saccarius*, cotypes", Australian Museum, W.1372. Of these, one specimen was closely examined and dissected.

Oreoscolex simulans (Fletcher, 1889b)

Figs 2B; 3D. Table C

Cryptodrilus simulans Fletcher, 1889b: 998–999.—Beddard, 1895: 505.

Notoscolex simulans.—Michaelsen, 1900: 193.—Jamieson, 1971b: 79.

Oreoscolex simulans.—Jamieson 1974: 303.

Table C

INTERSETAL DISTANCES IN SEGMENT XII

in *Oreoscolex simulans*

	mm								Standardized to percentage of periphery							
	aa	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*	*aa*	*ab*	*bc*	*cd*	*dd*	*dc*	*cb*	*ba*
W.1499 (1)..	1·26	0·53	1·30	0·80	4·00	0·69	1·42	0·53	12·00	5·09	12·36	7·63	37·81	6·54	13·45	5·09
W.1499 (2)..	1·11	0·38	1·15	0·73	4·23	0·73	1·15	0·38	11·28	3·89	11·67	7·39	42·80	7·39	11·67	3·89
Mean	..	..	..	..	..	..	..	..	11·64	4·49	12·01	7·51	40·30	6·96	12·56	4·49
Intervals/*ab*	..	..	..	..	..	..	..	..	2·59	1·00	2·67	1·67	8·97	1·55	2·79	1·00

Description:

l = 82–108 mm, w = 4–5 mm, s = 220. Prostomium pro-epilobous $\frac{1}{2}$, open. First dorsal pore 10/11. Setae indistinctly visible, in 8 regular longitudinal rows throughout.

Nephropores not visible. Clitellum 1/n XIII–XVII? (Fletcher). Male pores on two small papillae a little dorsal of *a* lines on the setal annulus of XVIII which presents a ridgelike swelling separated from similar but less pronounced ridges on XVII and XIX by depressions, the ends of the first and last ridges bending round and fusing with that on XVIII, their extremities reaching a little dorsal of setae *b*; a pair of what appear to be pores on the anterior annulus of XVIII and XIX (Fletcher) or (re-examination, W.1499 (1)) male pores very slightly ventral of *a* lines on the transverse swelling; an ill-defined ridge on XVII laterally connecting with this, the marking in XIX restricted to a transverse tumescence in 18/19 reaching the setal annulus of XIX and laterally to *b* lines but not connected with that in XVIII. Female pores anteromedian of setae *a* of XIV, approximately 1/3 *aa* apart. Spermathecal pores 2 pairs, in 7/8 and 8/9, a little dorsal (Fletcher) or very slightly ventral (re-examination) of *a* lines.

Last hearts in XII; those in X–XII latero-oesophageal. Supra-oesophageal vessel in IX–XII (?), well developed. Gizzard large and moderately firm, with anterior rim, in V. Three pairs of large reniform calciferous glands sessile dorsolaterally on the oesophagus, but well pinched off, in XIII, XIV and XV; each with many radial laminae crossing the entire lumen of the gland. Intestinal origin $\frac{1}{2}$ XVII; typhlosole absent but some segmental thickening of the roof of the intestine present; muscular thickening and caeca absent. Nephridia meronephridia: very large tufts in V with wide composite ducts passing forward to open into the pharynx shortly behind the brain. Nephridia further anteriorly reduced, exonephric, with a pair of small tufts in IV; aggregations of long exonephric tubules on the posterior septa of VI and several succeeding segments. Nephridia of the intestinal region many parietal exonephric micromeronephridia on each side which caudally have numerous preseptal funnels. Caudal nephridia also adherent to the intestine and possible enteronephric though no communication with the gut was demonstrable. Holandric (sperm funnels non-iridescent in X and XI); gymnorchous, seminal vesicles racemose, in XI and XII. Metagynous; ovisacs not seen. Prostates tubuloracemose, elongate, leaf-like and laterally incised, in XVIII and XIX, the thick muscular duct continuous as a midrib medianly through more than half of the length of the gland and giving off a succession of lateral ducts into the gland at rather regular intervals. Vas deferens joining junction of gland and muscular duct. Penial setae present. Spermathecae 2 pairs, in VIII and IX, the ampulla ovoid; diverticulum multiloculate but in this specimen borne on a distended muscular lateral duct which joins the long spermathecal duct near the ectal end of the latter.

Type-locality:

Bulli and Illawarra, New South Wales.

Material examined:

5 imperfectly sexual specimens labelled "*Crypto. simulans* (T.F.P. and T.G.S.), Bulli, 10/11/87, 16/10/89, and Appin" (date?), Australian Museum W.1499, apparently the syntypes, of which two were examined closely and one dissected.

Remarks:

The above account extends and confirms the original type-description excepting Fletcher's observation of only two pairs of calciferous glands.

ACKNOWLEDGMENTS

The author is indebted to Dr P. Hutchings, of the Australian Museum, for access to the material described, and to Mr E. A. Bradbury for his assistance. All drawings are by the author. The work is part of a project financed by Australian Research Grants Committee and Royal Society Nuffield grants.

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Contributions to the Knowledge of the Alpheid Shrimp of the Pacific Ocean Part XVIII: A New Species of the Genus *Alpheus* from the mouth of the Sepik River, New Guinea[1]

By

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Figure 1

Manuscript received, 16th January, 1974

Alpheus leptocheles sp. nov.

Holotype

31 mm male from mouth of Sepik River, New Guinea, between Cape Girgir and Kaup. Trawled between $1\frac{1}{2}$ and 10 fms. Collected by R. Eginton on the m.v. *Tagula,* Aug.-Sept., 1965. (Australian Museum reg. No. P.19917.)

Paratypes

Two female specimens from the same locality as the holotype (AM P.19918).

Description

Rostrum acute, longer than broad at base, reaching to middle of visible part of first antennular article, with slight rounded carina reaching posteriorly only to base of orbits. Orbits moderatedly inflated, forming moderately deep rounded grooves between rostral carina and orbits. Orbitorostral margin slightly concave. Carapace densely papillose, less abundant on dorsal surface, entire carapace sparsely pubescent. Visible part of first antennular article 0.6 as long as second, a little longer than third article; second article 2.4 times as long as broad. Stylocerite reaching almost to end of first antennular article, distal tooth turned slightly outward. Scaphocerite reaching slightly past antennular peduncle, lateral margin straight, squamous portion narrow, attaining level of tip of lateral tooth. Carpocerite stout, reaching to end of antennular peduncle.

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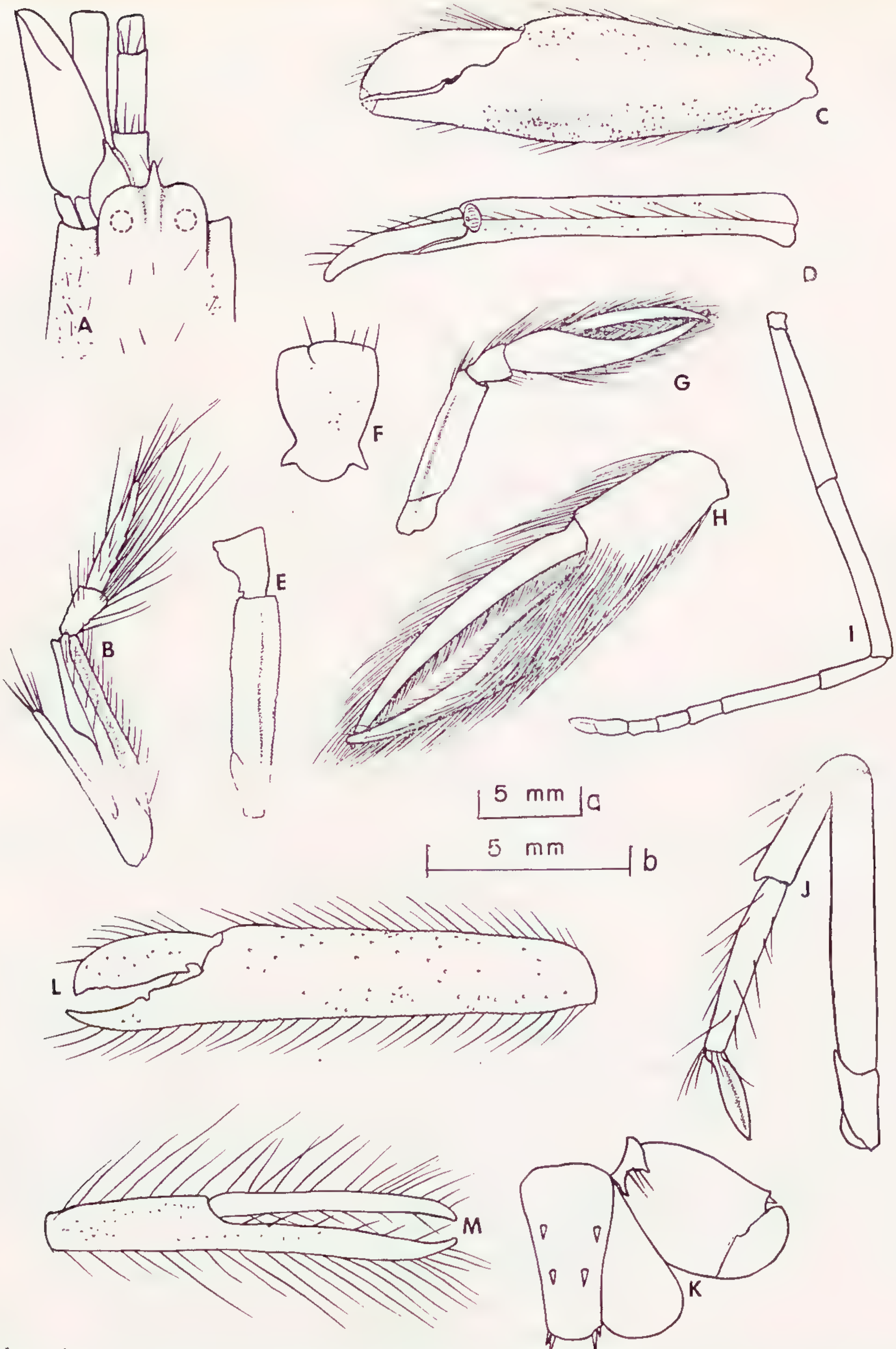
[2] Hawaii Institute of Marine Biology contribution number 458.



Alpheus leptocheles sp. nov.—Fig. 1. Holotype: A, anterior region, dorsal view. B, third maxilliped. C, large chela, lateral view. D, large chela, superior view (pollex obscured). E, merus and carpus large cheliped, lateral view. F, carpus, large cheliped, superior face showing proximal teeth. G, small cheliped, lateral view. H, small chela, medial view, enlarged. I, second leg. J. third leg. K, telson and uropods. Paratype, 30 mm female: L, large chela, lateral view. M, small chela, lateral view. C, D, E. G, scale a; A, B, F, H, I, J, K, L, M, scale b.

Entire surface of large cheliped of male finely papillose. Chela 3.7 times as long as broad. Palm with extreme lateral compression, 7.0 times as high as thick; area of maximum longitudinal thickness lying above middle with lower half of chela blade-like; both superior and inferior margins thinned to knife edges. Palm highest immediately proximal to dactylar articulation, tapering proximally, 1.7 times as broad immediately proximal to dactylar articulation as at carpal articulation. Dactylus sharply carinate, fingers very slim, curved slightly outward. Superior margin of palm with moderately long forward-sweeping hairs, superior margin of fingers also bearing hairs, but shorter than those of palm. Carpus cup-shaped, 0.15 as long as chela. Lateral margins of proximal region bearing subacute teeth directed proximally. Merus 4.3 times as long as broad, without armature. Lateral face near superior margin bearing deep groove extending from distal end of proximal portion of ischium. Large chela of female 5.8 times as long as broad also with knife-like margins but with margins almost parallel. Surface papillose, similar to that of male; superior and inferior margins bear long, fine forward-sweeping setae. Merus and carpus similar to those of male.

Small chela of male highly compressed, 5 times as long as broad, fingers 2.2 times as long as palm. Both fingers arched and gaping in middle, uniformly tapering to tip, tips crossing when closed. Superior and inferior margins of chela bearing long forward-sweeping hairs. Opposing surfaces of fingers bearing hairs directed forward which intermesh in middle. Medial face of chela much more hirsute than lateral, with dense tuft of hair near articulation of dactylus. Carpus and merus similar to those of large cheliped. Small chela of female nearly 8 times as long as broad, fingers a little less than 1.5 times as long as palm. Palm papillose and bearing along inferior and superior margins very fine forward-sweeping setae. Opposing surfaces of fingers bearing shorter fine setae that cross. Carpus and merus similar to those of male.

Ratio of carpal articles of second legs: 10:23:8:8:8.

Ischium of third leg without spine. Merus 7 times as long as broad, unarmed. Carpus 0.4 as long as merus; superodistal margin slightly projected. Propodus 0.6 as long as merus, bearing on inferior surface a few stiff setae and long hairs but no spines. Superior margin bearing several long hairs. Dactylus spatulate, 0.5 as long as propodus, superior surface with longitudinal ridge which bears patches of very short stiff setae on both sides.

Telson 3.3 times as long as posterior margin is broad. Dorsal pairs of spines small, anterior pair placed anterior to middle.

Discussion

The compressed large chela, the shape of the orbitorostral front and the flattened dactyli of the third legs, among other characteristics plainly put this species in the Brevirostris group of the genus *Alpheus*. As far as we have been able to determine the distal broadening and proximal tapering of the palm of the large chela and its extreme compression are unique to the group. Further characteristics separate this species from previously known species. It can easily be separated from many in the group by the lack of transverse notch behind the dactylar articulation of the large chela, and by the fact that the rostral crest or ridge does not extend posteriorly to well behind the orbital hoods. The description

and figures of *A. halesi* Kirk (1887: 194, pl. 6d) leaves ambiguities, but the heavy longitudinal ridge on the outer face of the large chela plainly separates it from this species. *A. macroskeles* Alcock & Anderson ("correct original spelling" as defined in International Rules of Zoological Nomenclature, Article 32 (a) (ii)) (1894: 153), *A. distinguendus* De Man (1909: 155, pl. 7, fig. 9–14), *A. pustulosus* Banner & Banner (1968: 143, fig. 2), *A. nonalter* Kensley (1968: 172, fig. 15) and *A. stephensoni* Banner and Smalley (1969: 45, fig. 2) have some manner of armature, either spines or teeth on merus of the large and small chelae, and only in *A. distinguendus* is the palm of the small chela of the male shorter than the fingers. In *A. stephensoni* the palm of the small chela of the male is about equal in length to the fingers, not markedly shorter than the fingers as in this species.

The differences between both chelae of the male and female could either be sexual dimorphism or be indicative of separate species. Certainly, sexually dimorphic small chelae are common in this genus, but sexually dimorphic large chelae occur only rarely, e.g., *A. idiocheles* Coutière (*see* Banner & Banner, 1967: 271). If we knew that these were collected from the same environmental niche, we would have no misgivings about pronouncing the differences to be sexually dimorphic. While the collection data were the same for the male as the females, the male was in a separate vial. This may indicate a separate habitat or even a separate trawl haul. If so, then we may have two species. However, because the specimens were so similar in other characteristics and similarly differ from other known species, we presently believe that we are dealing with a single sexually dimorphic species.

The specific name refers to the extremely compressed large chela.

The holotype and paratypes have been placed in the Australian Museum, Sydney.

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The Alpheid Shrimp of Australia

Part 2: The Genus *Synalpheus*

By

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Figures 1–29.

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SUMMARY

This is the second section of a projected tripartite study on the shrimp of the family in Australian waters; the first section (Banner & Banner, 1973), dealt with the lower genera, and contained also keys to the genera and locality lists for the entire collection; the third section will be confined to the genera *Alpheus, Metalpheus* and *Batella,* with notes on the related family Ogyrididae in Australian waters, and will also contain the bibliography for the series.

This study of the genus *Synalpheus* is based upon 1,437 separate specimens on loan from various Australian museums and other institutions and our personal collections. This section discusses the following species, with those which are new species or subspecies and those which are new records to Australian waters being marked by an asterisk.

**Synalpheus carinatus* (De Man)
**Synalpheus tropidodactylus* sp. nov.
Synalpheus comatularum (Haswell)
Synalpheus stimpsoni (De Man)
**Synalpheus quadriarticulatus* sp. nov.
**Synalpheus pescadorensis* Coutière
**Synalpheus sciro* sp. nov.
**Synalpheus bituberculatus* De Man
**Synalpheus harpagatrus* sp. nov.
**Synalpheus theano* De Man
Synalpheus neptuntus neptunus (Dana) [subspecies designated]
**Synalpheus neptunus germanus* subsp. nov.
**Synalpheus demani* Borradaile
**Synalpheus nilandensis* Coutière

**Synalpheus heroni* Coutière
Synalpheus fossor (Paulson)
Synalpheus haddoni Coutière
Synalpheus coutierei Banner
**Synalpheus bispinosus* De Man
**Synalpheus ancistrorhynchus* De Man
**Synalpheus lophodactylus* Coutière
**Synalpseus hastilicrassus* Coutière
Synalpheus neomeris (De Man)
**Synalpheus streptodactylus* Coutière
Synalpheus pococki Coutière
**Synalpheus iocosta* De Man
Synalpheus charon (Heller)
**Synalpheus gracilirostris* De Man
**Synalpheus echinus* sp. nov.
Synalpheus tumidomanus (Paulson)
**Synalpheus paraneomeris* Coutière

We have placed the following species and subspecies in synonymy:

S. stimpsoni (De Man) synonyms:
S. amboinae (Zehntner); *S. brucei* Potts; *S. striatus* Kubo.

S. fossor (Paulson) synonyms:
A. sp. variatas De Man; *S. bakeri* Coutière; *S. bakeri stormi* De Man.

S. hastilicrassus Coutière synonyms:
S. acanthitelsonis Coutière; *S. hastilicrassus acanthitelsoniformis* De Man

S. neomeris (De Man) synonym:
S. gravieri Coutière

S. streptodactylus Coutière synonym:
S. streptodacytlus hadrungus Banner & Banner

S. charon (Heller) synonym:
S. prolificus (Bate)

S. tumidomanus (Paulson) synonym:
S. maccullochi Coutière; *S. anisocheir* Stebbing

Fourteen nominal species and subspecies have been reported from Australian waters; of these, we have been able to confirm 12, but we have placed 3 of the 12 in synonymy. Of the remaining two, one, *S. haddoni* Coutière, we have carried on our lists although it is not represented in the present collections; the other, *S. latastei* Coutière (1909), we could not confirm and, as it was listed with doubts by the original author, we suggest that the listing was in error.

CONTENTS

INTRODUCTION

In this second section of our projected tripartite study we are confining ourselves to the genus *Synalpheus*. The reader is referred to the initial publication (Banner & Banner, 1973: 294) for a statement of our aims, the adequacy of our sampling, general notes of biology, distribution and ecology of alpheids, the keys to the genera, and for the collection data which is listed in this section under the alphanumerical code. As in Part I (page 306) measurements in millimetres given for the size or length of specimens are always the total length from rostrum to tip of telson unless carapace length is specified. In the third section we plan to publish on the two closely related genera, *Alpheus* and *Metalpheus*, discuss *Batella* and give notes on the related family Ogyrididae. The last section will contain the full bibliography for the three sections and data on additional collections.

We did not remark in Part I that we are studying several other collections concurrently with the study of the Australian species. The most important of these collections come from the Philippines, Indian Ocean and Red Sea; while we plan to publish upon them separately in the form of regional annotated checklists, we have used them where desirable to broaden the basis of our systematic considerations. We have also referred to specimens in these collections under our section on "General Distribution". These unpublished records we have marked with an asterisk.

Support and acknowledgments:

Our support and acknowledgments of aid are the same as those listed in Part I, and again we wish to express our deep thanks to those individuals and institutions who have been so helpful to us in this protracted study. We must repeat our acknowledgment of the financial support from the U.S. National Science Foundation through grants GB3809, GB6386 and GB25020.

Genus SYNALPHEUS

Synalpheus Bate, 1888, Challenger Rept. Zool. 24:572*

Type species: *Synalpheus falcatus* Bate, 1888 (= *Alpheus comatularum* Haswell, 1882)

Definition: Rostrum and orbital hoods always developed, orbital hoods completely enclosing eyes from dorsal and anterior aspects. Orbitorostral process usually well developed and protruding ventrally to low ocular beak; both processes lacking in some species. Pterygrostomial angle produced, usually subacute and rounded.

Antennules with basal articles heavy, stylocerite with lateral spine well developed, flagellum with weak bifurcation. Scaphocerite with squamous portion always shorter than lateral spine, and rudimentary in some species. Basicerite bearing one or more teeth.

Mandibles at times with *pars incisiva* reduced. Last article of third maxilliped bearing either setae or spines at tip.

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* While Bate established the genus, it was not given its presently accepted definition until Coutière published his monograph in 1899; it was also at this time that most species previously assigned to *Alpheus* were included (for a full discussion see De Man, 1911: 185).

Large chela massive, carried extended, ovoid and without sculpture; dactylus short and almost always with cylindrical process fitting into chamber at base of pollex; carpus cyathiform. Small chella markedly smaller than large, simple, with fingers usually unarmed and fitting exactly; carpus frequently elongate.

Second pereiopods with carpus usually of five articles, in a few species of four articles. Following legs short and compressed, dactyli with two or three ungui.

Endopod of second pleopods of male lacking in the *appendix masculina.*

Sixth abdominal segment without articulated pleura. Uropods normal in most species, but lacking articulation in outer uropod in some. Telson lacking anal tubercles and posterior margin convex to straight. Caudal fan carrying exceedingly large spines on some species.

Branchial formula: 5 pleurobranchs, 1 arthrobranch, 2 epipodites; no mastigobranchs or setobranchs.

Discussion

Separation of Synalpheus from Alpheus

This genus is most closely related to the genus *Alpheus,* and to one unaccustomed to the appearance of members of both genera the assignment of the species between the two may present difficulties. The most certain criteria for the separation of the genera are the produced pterygostomial angle on the carapace in *Synalpheus* (see fig. 3a) and the branchial formulae which lacks six of the epipodites found in *Alpheus.* With the diversity of characteristics found in both large genera, no other single characteristic can be completely relied upon. However, if the exceptions are kept in mind, the following tabulation may be of value:

	Synalpheus	*Alpheus*
Rostrum and orbital teeth	Always developed, seldom with crests or ridges	Of varying development often without orbital teeth, often with a rostral crest
Large chela	Always ovoid in section, never with sculpturing	Seldom ovoid in section, usually with a combination of compression, twisting, and sculpturing
Carpus, second legs	First article usually about as long as sum of distal four articles	Variable, usually with first article shorter than sum of four following articles
Dactylus of third legs	Always bi- or tri-unguiculate	Usually simple, biunguiculate in a few.

Subgeneric groups:

In 1908b and then more fully in 1909, Coutière established six groups of species within the genus that were supposed to show evolutionary patterns and subgeneric affinities. To each "group"—he did not apply the term "subgenus"—he gave the name of one of the characteristic species found within it. This procedure of naming has caused two of his groups to change names when the species names were synonymized (see below).

What utility the groups originally had we cannot determine at this time except to say that they were accepted by Coutière's contemporary, De Man (" . . . six groups that are quite natural and that therefore are also accepted by me." 1911: 189). However, the addition of many new species, especially by De Man and the later works of Coutière, caused greater and greater modifications of the definition of the groups. We had hoped to be able to use these collections and this paper for a complete reassessment of Coutière's groups, either their redefinition and re-establishment or for a substitution of another "subgeneric" scheme of separation of the numerous species found in the genus. Our considerations of the individual groups, together with the Australian species that appear to belong to each group, are given below:

Comatularum Group:

Australian species: *S. carinatus, tropidodactylus, comatularum, stimpsoni.*

Notes: This group seems to be well separated from the other synalpheids by a series of characteristics:

1. The orbitorostral process is lacking (we plan to discuss the orbitorostral process and the associated ocular beak in a future paper).

2. The frontal region of the carapace is produced far beyond the eyes; the rostrum usually bears a crest and is markedly longer than the orbital teeth.

3. The merus of the third leg never bears spines, and the dactylus usually has the ungui hooked and the inferior unguis is always narrower in basal width and shorter than the superior.

In addition, most species live in association with crinoids (see Appendix). We have considered whether this group is distinct enough to raise to a separate generic level (in which case it would have to retain the name *Synalpheus*), but have decided that such a revision is unnecessary at this time.

Neomeris Group:

Australian species: *S. demani, nilandensis, heroni, fossor, neomeris, streptodactylus, pococki, iocosta, charon, paraneomeris.*

Notes: The principal characteristics for the group emphasized by Coutière were that the superior unguis of the third dactylus was always smaller than the inferior and that the orbital teeth were always longer than broad at the base. We have found that at least in *S. paraneomeris* and *S. streptodactylus* the relationship between the ungui is variable and the ungui may approach equality; similarly, the orbital teeth are variable in a number of species and they cannot be clearly separated from those of many other synalpheids. Other characteristics, such as the presence of an orbitorostral process and the tapering dactylus of the small chela which is also without a row or tuft of setae, are found in common with most of the other synalpheids. We therefore find the group to be neither of taxonomic use nor of systematic importance.

Paulsoni Group:

Australian species: *S. ancistrorhynchus, hastilicrassus, gracilirostris, echinus, tumidomanus.*

Notes: Coutière characterized this group as (1) with two ungui of the dactylus of the third leg equal in breadth and both long and slender; (2) without spines on the merus of the third legs; (3) with orbital teeth always longer than wide; (4) with having an orbitorostral process; a few other characteristics were also given. Even in this small number of Australian species, we found each part of the definition be to violated by one or more species, or to be so variable within a species as to be unreliable. The sole exception in the presence of the orbitorostral process, but many other synalpheids share this characteristic. We find that this nominal group is not useful.

Brevicarpus Group:

Australian species: none.

Notes: This small group, known only from American waters, was distinguished by Coutière principally by the lack of an orbitorostral process and by the short rostrum and orbital teeth. He did not remark that both the Comatularum and the Gambarelloides (= Laevimanus) Groups also lack the orbitorostral process. The formation of the anterior region of the carapace appears to be a fair characteristic for the group and certainly separates it from the Comatularum group; the lack of a crest of setae on the dactylus of the small chela separates it from the Gambarelloides group. However, our examination of species of this group at the Smithsonian Institution showed that the lack of an orbitorostral process was not consistent. In *S. minus* (Say) (= *S. brevicarpus* (Herrick) see Chace, 1972: 95) we found that some specimens, but not all, have a plate of varying development on the ventral side of the rostrum and this plate may be developed into a small process. In *S. digueti* Coutière a small but definite process is always present. These two species definitely have the reduced rostrum and orbital teeth characteristic of the group. As there are no species assigned to this group in our Indo-Pacific collections we will not evaluate its worth further.

Gambarelloides Group (previously Laevimanus Group—see Holthuis, gottlieb, 1958: 48)

Australian species: possibly *S. haddoni.*

Notes: This group also is known almost entirely from American waters, with the exception of two Mediterranean species and possibly the species listed above. Coutière characterized the group by a "brush" of thick and crowded long hairs normal to the dactyl of the small chela. Our examination of the specimens of species of this group at the Smithsonian Museum and the American Museum of Natural History indicates that this appears to be a consistent characteristic, not found in comparable development elsewhere in the genus. The orbitorostral process was also lacking in these species except for *S. anisimanus* Chace; this species, however, had only a thickened horizontal plate and no projecting process. Again, as we have no species of this group in our Indo-Pacific collections, we refrain from additional evaluation.

Coutièrei Group (previously Biunguiculatus Group—see Banner, 1953: 37)

Australian species: *S. quadriarticulatus, pescadorensis, sciro, harpagatrus, theano, neptunus neptunus, neptunus germanus, coutierei, bispinosus, lophodactylus.*

Notes: This group is characteristically an Indo-Pacific Group and is the largest in Australian waters. As defined by Coutière it had no firm characteristics, such as the brush of hairs on the small chela for the Gambarelloides group. Some members of this large and variable group of species from Australia violate each characteristic as set forth by the definition; therefore the group cannot be regarded as coherent.

Seven species within the group, however, seem to be set off, but rather poorly, from all other species of synalpheids. These are the species with broadened and dentate fingers of the small chela; the fingers often have more than one tooth and usually are excavate. They are found in the following key from dichotomies 6 to 12, inclusive. However, there appears to be two rather fundamental differences in the group thus united by the form of the fingers. Three lack the orbitorostral process and also lack a distal articulation of the outer uropod; the other four species have both the process and the articulation. We believe that to separate these species into subgeneric groups would not be of any great advantage.

Thus of the six groups erected by Coutière, only three may be coherent enough to continue to be recognized; of these three, only one occurs in the Indo-Pacific (with the possible exception of the Gambarelloides group). The other three groups into which the great bulk of the Indo-Pacific species have been assigned, are of "dubious relationships and are of almost no aid in classification" (Banner, 1953: 28). To our knowledge, no other author since Coutière has taken this stand, but we note that Chace (1972: 79–104) did not utilize the groups when classifying the synalpheids, and that he remarked on his only new species outside the well-defined Gambarelloides group: "*Synalpheus obtusifrons* seems to belong to the Brevicarpus group of the genus" (underlining ours).

Variation in the synalpheids

Compared to the members of the genus *Alpheus,* the species in this genus are remarkably uniform in appearance. Most show but little difference in the frontal region of the carapace; there is only slight variation between species in the antennular and antennal peduncles; the large chela varies principally in the armature above the dactylar articulation; the first carpal article of the second legs usually is about equal to the sum of the four following; even the dactylus the third leg is usually biunguiculate.

Previous workers, faced with this uniformity of characteristics, began to rely upon rather small and subtle differences to differentiate between species or subspecies. This differentiation appeared to be satisfactory when the worker had only a few specimens; however, when large numbers of specimens were at hand they encountered such variation that at least Coutière responded by creating a large number of supposedly discrete subspecies (see Coutière, 1909: *passim*).

The amount of variation we have found in our large collections of some species is indeed confusing. Thus *Synalpheus charon* varies in the length of the stylocerite, but is fixed in configuration of the unusual dactylus of the third leg; on the other hand, *S. noemeris* and *S. streptodactylus* are quite constant in the development of the stylocerite, but quite variable in the proportions of the ungui of the third leg. In some, like *S. theano* and *S. neptunus neptunus,* the squame

varies from moderate development to occasionally rudimentary; *S. bituberculatus* may lack the supposedly characteristic two tubercles above the dactylar articulation of the large chela; *S. hastilicrassus* shows wide, but apparently continuous variation in the development of teeth on the posterolateral corners of the telson. Yet some rather small characteristics seemingly are constant: as we pointed out in an earlier paper (Banner & Banner, 1972), the only way that *S. theano* and *S. n. neptunus* can be separated is by the armature of the distal article of the third maxilliped.

This variation could be explained if it occurred only in those species which are found in symbiotic relationship with sponges, crinoids, etc. Thus, in the protection of a spongocoel, the variation in the dactylus of the third leg in *S. streptodactylus* would make little difference in survival, or if *S. comatularum* has the strongly hooked dactyli of the walking legs, and the scimitar-shaped dactylus of the small chela for holding to its host crinoid, differences in the length of the rostrum and orbital hoods might have no survival value. However, the variation is not confined to those forms in symbiotic relationship, and those which may be found either free living or in a host show parallel variation in both habitats. *S. paraneomeris*, apparently never found in a symbiotic relationship is one of the most variable of all synalpheids.

So we are left with species that have been separated by subtle differences and that are variable in those characteristics used for their separation. It is obvious that many of the previously described species will be found to be synonyms when larger collections are made; in a few cases, like *S. n. neptunus* and *S. theano* mentioned above, new characteristics may be found that will validate their separation. For the most part, however, we agree with Chace when contemplating Coutière's numerous subspecies of American synalpheids, "Their prevalence [e.g., of varietal differences] emphasized the amount of variability encountered in this genus and the difficulty in finding specifically stable characteristics."

At times in this study we could not reach any firm conclusions as to whether or not we were dealing with a widely variable single population, or with a subspecific or even specific difference, we have pointed out these variations, but except in one case (*S. neptunus germanus*) we have refrained from the use of subspecific names. In one species (*S. nilandensis*) we have resorted to the device of labelling differences as "forms", knowing that the use of this device will not give the names applied any conservation under the rules of nomenlature.

We are even at loss for suggestions to future workers for the resolution of the problem of variation and the separation of the species. It may be that adequate colour notes may aid in the separation, but some species, like *S. comatularum* has been reported to vary with the colour of its host. With species, like *S. neomeris,* which appears to vary their habitats from free-living to a symbiotic life with a series of hosts and which show no correlated morphological changes, it is obvious that a detailed study of their environmental needs would be fruitless. Possibly the only resolution will be in the almost impossible task of investigating the genetics of each species—its chromosomal count, its ability to cross-breed, the variation found within offspring from various parental pairs. It is doubtful if the problem would warrant such excessive expenditure of research time.

*Symbiosis in the synalpheids**

Of the thirty-one species and subspecies of this genus from Australia, three have been reported only as symbionts on sponges, one living only on coral and one only on crinoids; nine have been reported both from sponges and from "dead coral" and two have been reported both from crinoids and as living in non-symbiotic relationships. Several have been reported as "dredged" without any further notes on habitat. We suspect that some of the dredged specimens may have been actually in symbiotic relationship, especially on crinoids, but were displaced from their hosts by the violence of the collections. For example, R. U. Gooding remarked on specimens of *S. carinatus, S. stimpsoni* and *S. demani* that were collected in a trawl off Samarai, Papua, "Virtually the whole haul consisted of comatulids [Crinoida] and some of the shrimp were collected directly from these, but others were loose." Correspondingly during the collection of shrimp by breaking up dead coral heads, the shrimp may fall out of a sponge lodged between the branches as well as from between the branches themselves. Thus, the mere lack of records of symbiotic association does not prove the association did not exist.

However, it is apparent that some species are not obligate symbionts. The contrast of the records of *S. lophodactylus* and the related *S. hastilicrassus* in Australian waters will illustrate the point. All but 7 of 208 specimens of the first species were collected from sponges, most of which were thrown on to a beach by a storm; one would suspect that the 7 escaped from broken sponges. On the other hand, 22 specimens of *S. hastilicrassus* were found in dead coral and only 10 were reported from sponges. *S. stimpsoni* of the Comatularum group is most commonly reported in a symbiotic association, but it was collected intertidally from heads of dead coral and under rocks by a number of trained biologists. Possibly the most strange associations are those of *S. neomeris* which in these collections has been reported from the standard dead coral, from live alcyonarians, from sponges and even from bryozoan colonies. Miya records that *S. bituberculatus* in Japan came similarly from sponges, living corals and alcyonarians.

To our knowledge little has been reported on the nature of the symbiotic relationship between the alpheid and the host except for some of the species in the Comatularum group (*see* Appendix, p. 387). Some of these were seen taking food from the mucous train in the ciliated ambulacral groove of the host. Others have been suspected of using the host for shelter and protection—it is likely that *S. charon*, and *Alpheus lottini* Guérin, uses the host coral for protection, feeding largely upon small invertebrates and algae that they find, but occasionally eating mucous and bits of coral tissue (Barry, 1965: MS thesis). Correspondingly the shrimp in a spongocoel may be there for protection and feed upon particles of food swept into the cavity by the sponge's feeding currents. These particles would be too large for ingestion by the choanocytes of the sponge, so there would be no competition between the associates for food. However, when scores, even hundreds of shrimp are found in a single sponge, as *S. streptodactylus* is found in *Zygomycale parishii* (Bowerbank) in Hawaii, one would suspect a relationship that may be deleterious to the host, and possibly present a case of actual parasitism. In this connection in may be noted that most of the species with subspatulate and denticulate fingers on the small chela at times occur in sponges,

* We have used the term symbiosis in the modern sense of the two animals living together, without implication of benefits to either of the pair.

and that the fingers would appear to be an excellent tool for the tearing off pieces of sponge tissue; perhaps these too may be playing a role other than innocent symbiotism.

Finally under symbiotism the strange case of *Synalpheus neptunus germanus* should be noted. As recorded below (p. 321) all 44 specimens in the collection came from spongocoels, and all 44 were of small size and were sexually immature. One recalls Coutière's report (1909:17) of a single dredge haul of the *Albatross* that produced 5 000 to 6 000 specimens of *S. longicarpus* (Herrick) and *S. pectiniger* Coutière in which none seemed to be of normal size and of sexual maturity—of 227 females examined he could only find "two or three in which the pleura were normal and the eggs present . . . none with the very large eggs carried by normal females". We discuss this anomaly further under the species.

Previous Australian records of synalpheids

Fourteen species and subspecies of *Synalpheus* have been previously reported from Australia in the literature. Nine of these were indicated in the summary (p. 267), and three others have been placed in synonymy: *S. bakeri* Coutière, *S. bakeri stormi* De Man and *S. maccullochi* Coutière. One, originally named *S. laevimanus haddoni*, was not found in the collections but is listed as *S. haddoni* for the description permits its separation from all other Australian synalpheids. The last species, *S. latastei* Coutière (1909: 26), is an American species described from Chile, and was recorded from Australia by that author with the remark: "the species is also met with in Australia (?) [sic]) (one male of great length without indication of locality other than New Holland; Paris Museum)". As the species has not been recorded from anywhere else in the Indo-West-Pacific, as it is large and as it would be difficult to confuse with others we have found in Australia, we have concluded that it probably does not occur in Australia and that the doubts about its record from Australia indicated by Coutière were probably correct. As it does not occur in these collections we do not wish to comment on the validity of its specific name (*cf.* Holthuis 1952: 36 and Crosnier & Forest 1966: 298).

KEY TO THE SPECIES OF THE GENUS SYNALPHEUS IN AUSTRALIAN WATERS

(*S. latastei* Coutière is omitted from this key)

1. Without orbitorostral process 2

— With orbitorostral process 8

2. (1) With rostrum extending beyond end of first antennular article and markedly longer than orbital teeth; dactylus (free finger) of small chela triangular and acute; exopod of uropod with subterminal articulation 3

— With rostrum markedly shorter than first antennular article and subequal to orbital teeth; dactylus of small chela broadened; excavate and at times with teeth; outer uropod without subterminal articulation.................................... 6

3. (2) With strong, acute tooth in middle sector of inferoexternal margin of merus of large chela 4

— Margins of merus of large chela with at most terminal teeth........ 5

4. (3) Carapace with dorsal carina extending posterior to eyes; orbital teeth one-third or more length of rostrum; dactylus of large chela with normal plunger .... *S. carinatus* (p. 283)

— Carapace with dorsal carina terminating at level of eyes; orbital teeth small, less than one-quarter length of rostrum; dactylus of large chela with plunger modified into a longitudinal crest...... .... *S. tropidodactylus* (p. 286)

5. (3) Dactylus of small chela sickle-shaped, longer than pollex (fixed finger) and with tip crossing pollex; dactylus of third legs with inferior unguis almost rudimentary, forming a right angle to the proximal margin .... *S. comatularum* (p. 289)

— Dactylus of small chela normal, almost straight, tip not crossing that of pollex; dactylus of third leg with inferior unguis acute and projecting, but smaller than superior unguis ...... *S. stimpsoni* (p. 292)

6. (2) Antennal squame rudimentary; carpus of second legs of four articles .... *S. quadriarticulatus* (p. 297)

— Antennal squame well developed; carpus of second legs of five articles 7

7. (6) Sympodite (protopodite) of uropods with tooth about half as long as outer uropod; spatulate dactylus and pollex of small chela terminating each in a single tooth .... *S. pescadorensis* (p. 301)

— Sympodite of uropods with tooth of normal size, about one-third length of outer uropod; spatulate dactylus and pollex of small chela terminating in several teeth .... *S. sciro* (p. 304)

8. (1) Dactylus of small chela at least broadened at base, subspatulate; tips of both fingers of small chela may bear several teeth............ 9

— Dactylus of small chela conical, never spatulate, fingers terminating in a single tooth.. 13

9. (8) Dactylus of small chela broadened only at base, with tip tapering; inferior margins of merus and carpus of small cheliped with conspicuous rows of fine spines .... *S. bituberculatus* (p. 307)

— Dactylus of small chela broadened and excavate to tip; inferior margins of carpus and merus of small cheliped with at most scattered setae 10

10. (9) Distal third of inferior margin of merus of third legs with conspicuous row of spines; both dactylus and pollex of small chela with teeth at tip .... *S. harpagatrus* (p. 311)

— Merus of third legs unarmed; pollex of small chela with a single acute tip 11

11. (10) Tip of third maxilliped bearing only fine setae .... *S. theano* (p. 314)

— Tip of third maxilliped bearing circlet of short heavy spines........ .... *S. neptunus* 12

12. (11) Squame reduced but present; dactylus of small chela without row of setae near crest .... *S. neptunus neptunus* (p. 317)

— Squame of scaphocerite lacking; dactylus of small chela with row of setae on outer face below crest ...... *S. neptunus germanus* (p. 321)

13. (8) Dactylus of third legs triunguiculate, but with inferior unguis at times reduced to a subacute angle 14

— Dactylus of third legs biunguiculate, never more than slight swelling as indication of third unguis 17

14 (13). Spines on propodus of third legs confined to distal quarter or less; dorsal spines of telson either greatly reduced or absent.......... .... *S. demani* (p. 324)

— Propodus of third legs with spines along entire length; dorsal spines telson always present and conspicuous 15

15 (14). Merus of third legs with two or more spines distally on inferior margin .... *S. nilandensis* (p. 327)

— Merus of third legs always unarmed 16

16. (15) Posterolateral corners of telson forming right angles, not projecting; squame reduced, narrower than adjacent spine; pollex of large chela proximally with rounded excavation on inner face........ .... *S. heroni* (p. 322)

— Posterolateral corners of telson projecting and acute; squame never reduced to narrower than adjacent spine; pollex of large chela normal, not excavate .... *S. fossor* (p. 325)

17. (13) Dactylus of small chela with a definite longitudinal row of setae on crest or on inner face; dactylus and pollex may bear other setae, but not in patterned rows 18

— Dactylus of small chela bearing setae, but not in rows or patches.... 23

18. (17) Squame either absent or at most reaching to near end of first antennular article . . . . *S. haddoni** (p. 341)

— Squame present and reaching at least to middle of second antennular article, usually beyond 19

19. (18) Posterolateral corners of telson normally forming right angles, at most slightly projecting 20

— Posterolateral corners of telson strongly projecting and acute 21

20. (19) Margins of sixth abdominal segment rounded on either side of telsal articulation . . . . *S. coutierei* (p. 343)

— Margins of sixth abdominal segment projecting as acute teeth on either side of the telsal articulation . . . . *S. bispinosus* (p. 346)

21. (19) Merus of third legs usually bearing several spines; if not, then with patches of setae; tips of rostrum and orbital teeth turned upward when seen in lateral view . . . . *S. ancistrorhynchus* (p. 347)

— Merus of third legs with neither spines nor patches of setae; rostrum and orbital teeth following normal curvature, not upturned 22

22. (21) Stylocerite shorter than first antennular article, and shorter than outer tooth of basicerite; row of setae on dactylus of small chela medial to crest of finger; outer angles of telson small . . . . *S. lophodoctylus* (p. 350)

— Stylocerite reaching beyond end of first antennular article, and equal to outer teeth of basicerite; row of setae on dactylus of small chela on crest of finger; outer angles of telson usually heavy and strongly projecting . . . . *S. hastilicrassus* (p. 353)

23. (17) Merus of third legs bearing two or more spines in inferior margin 24

— Merus of third legs without spines 27

24. (23) Superior unguis of dactylus of third legs less than half as long and less than half as broad at base as inferior unguis; numerous spines on merus of mature individuals . . . . *S. neomeris* (p. 357)

— Superior unguis of dactylus of third leg larger than above, approaching equality in size to inferior 25

25. (24) Ungui of dactylus of third legs of normal size, one-third to one-quarter total length of dactylus; numerous spines on merus of third legs of mature individuals . . . . *S. streptodactylus* (p. 362)

— Ungui of dactylus greatly reduced, no more than one-sixth and often one-tenth total length; only two spines on merus of third legs of mature individuals 26

26. (25) With only two spines, plus one or two terminal spines, on propodus of third legs; propodus with distinct superior curvature . . . . *S. pococki* (p. 366)

— With numerous spines on propodus of third legs, propodus only slightly curved . . . . *S. iocosta* (p. 368

* The small chela of this species has not been figured or described; however as Coutière first described the species as a subspecies of *S. laevimanus*, we are presuming it has the tuft of setae on the dactylus like *S. laevimanus*.

27. (23) Superior unguis of third legs broadened laterally into plate; inferior unguis very heavy and excavate on inferior surface.... *S. charon* (p. 369)

— Both ungui of dactylus of third legs conical and tapering, neither broadened nor excavate 28

28. (27) Rostrum long and slender, reaching beyond middle of second antennular article, five or more times as long as broad at base.... .... *S. gracilirostris* (p. 372)

— Rostrum shorter and more triangular, not reaching beyond end of first antennular article and not over three times as long as broad at base 29

29. (28) Terminal article of third maxilliped bearing on inner face numerous elongate spines.................................. *S. echinus* (p. 374)

— Terminal article of third maxilliped bearing only setae on inner face with usual circlet of short spines at tip........................ 30

30. (29) Dactylus of third legs with uniform taper and with superior unguis longer and often heavier at base than inferior....*S. tumidomanus* (p. 377)

— Dactylus of third legs with slight swelling on inferior surface proximal to inferior unguis; inferior unguis equal in length to, but thicker at base than superior .... *S. paraneomeris* (p. 383)

Synalpheus carinatus (De Man)

Fig. 1 and Fig. 2n

Alpheus carinatus De Man, 1888a, Arch. Naturgesch. 53 (1): 508, pl. 22, fig. 2.

Synalpheus carinatus De Man, 1911, Siboga Exped. 39a[1] (2): 210, pl. 6, fig. 23. Banner & Banner, 1968, Micronesica 4 (2): 272.

Synalpheus carinatus var. binongcensis De Man, 1909a, Tijdschr. ned. dierk. Vereen. II, 11 (2): 111; 1911, Siboga Exped. 39a[1] (2): 211, pl. 6, fig. 23a.

Synalpheus carinatus var. *ubianensis* De Man, 1909a, Tijdschr. ned. dierk. Vereen. II, 11 (2): 111; 1911, Siboga Exped. 39a[1] (2): 212.

Nec Synalpheus carinatus Pearson, 1905, Rep. Pearl Oyst. Fish., Ceylon, p. 83, pl. 2, figs. 9. [= *S. trispinosus* De Man]

Specimens examined: 4 specimens from AM 209; 2, AM 231; 2, AM 384; 2, AM 394; 1, WM 64–65; 3, WM 88–65; 1, WM 171–65.

Diagnosis: Anterior region of carapace depressed. Rostrum reaching to middle of third antennular article, concave in lateral view. Rostrum and carapace bearing strong median carina which continues almost entire length of carapace; carina compressed and knife-like in gastric and anterior cardiac region, and bearing slight notch in anterior gastric region. Carapace with a "humped" profile to the gastric region, "hump" more pronounced in females than males. Orbital teeth 0.4 as long as rostrum, tilting upward above rostrum and bearing rounded carinae that disappear posterior to corneas. Anterior region between rostral and orbital carinae depressed as moderately deep grooves. Carapace over antennular base inflated and separated from orbital hoods by deep grooves. Pterygostomial angle subacute, but not projecting. Rostral base without orbitorostral process.

Visible part of first antennular article almost 1.5 times longer than second article; second a little longer than third. Stylocerite reaching to middle of second antennular article. Scaphocerite with squamous portion narrow and reaching to end of antennular peduncle. Lateral spine prominent, longer than squamous portion and curved inward. Carpocerite as long as antennular peduncle. Basicerite with divergent inferior and superior teeth; superior tooth as long as orbital teeth, inferior tooth longer than superior.

Large chela slightly compressed, 3.5 times as long as broad; fingers occupying the distal 0.4. Carpus with superior margin bearing two widely set distal teeth, inferior margin with one acute tooth. Merus 2.7 times as long as broad; inferointernal margin terminating in sharp angle, superior margin projecting into an acute tooth. Superior margin of ischium bearing short heavy spine.

Small chela four times as long as broad with fingers 0.4 the total length. Dactylus straight, not hooked, armature of merus, carpus and ischium similar to that of large chela.

Ratio of carpal articles of second leg: 10:3:1:1:4.

Merus of third leg five times as long as broad, carpus half as long as merus, bearing terminally a superior rounded protrusion and an inferior small spine. Propodus as long as merus, bearing on its lower margin, 12–14 spines. Dactylus biunguiculate with ungui curved at right angles to propodus. Superior unguis about three times as long as inferior.

Telson three times as long as posterior margin is broad. Dorsal spines located well posterior of middle. Posterior margin between posterior spines strongly convex.

Discussion: As we pointed out for the specimens from the Marshall and Caroline Islands this species is variable (1968: 272). The cardiac notch varies from well developed to absent; the tip of the rostrum may reach from the middle of the second antennular article to one-half the length of the third antennular article; and the lower tooth of the basicerite may reach from three-fourths the length of the first antennular article to one-fourth of the second. We concluded that the varietal forms described by De Man were within the range of normal variation for the species. We have found the same range of variation in the Australian specimens.

Pearson (1905: 83, pl. 2, fig. 9) reported that his specimen from Ceylon carried three spines on the posterior margin of the sixth abdominal somite. As the condition has not been reported elsewhere nor found in the collections, we believe Pearson's specimens to be *S. trispinosus* De Man.

For the characteristics that distinguish *S. carinatus* from its closest relatives in Australia *see* Table I.

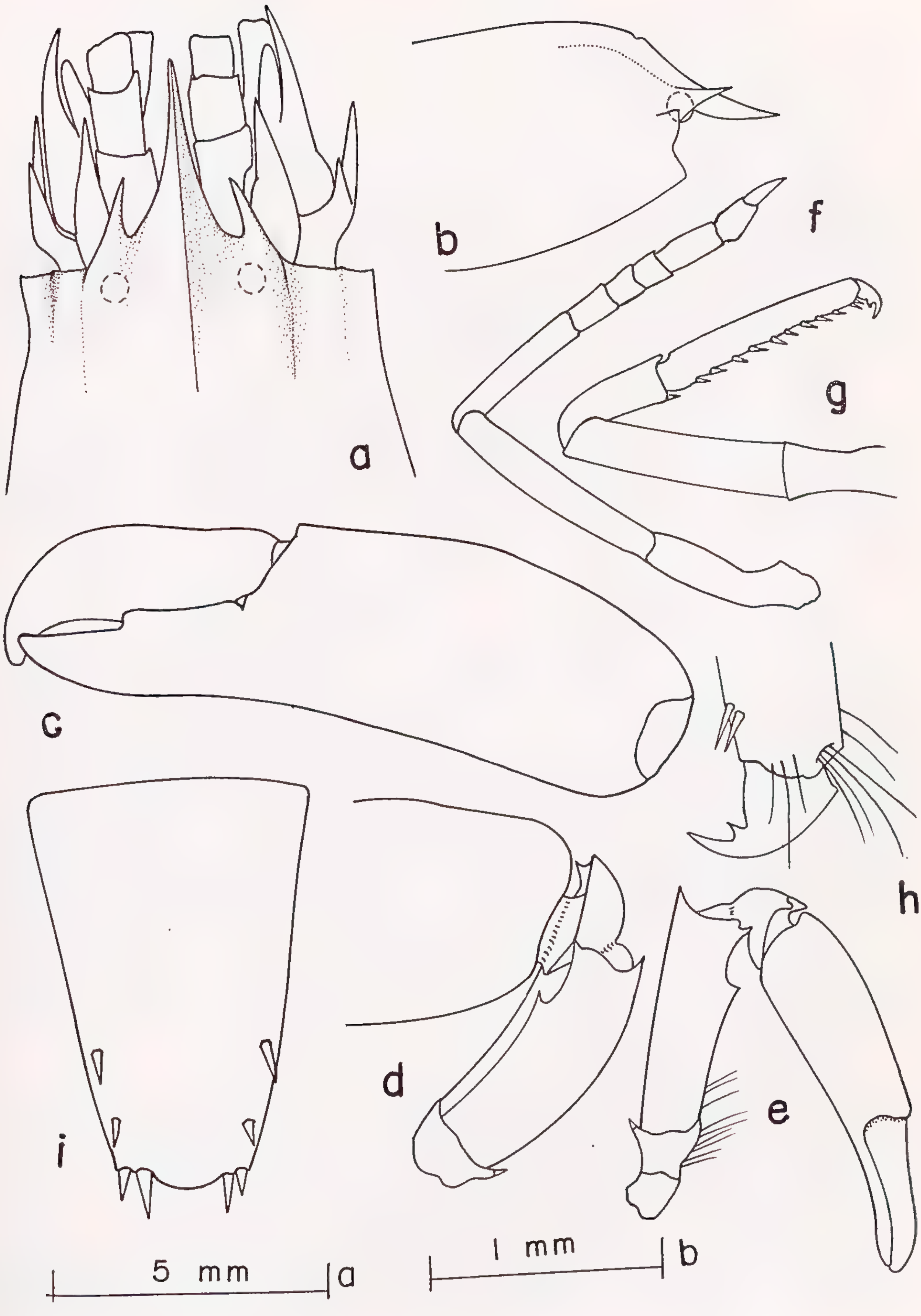
Biological notes: This species has been reported to be associated with crinoids; however, in some collections, as those from Western Australia, no host has been recorded. When associated with crinoids it assumes the colour of its host. Two of the specimens from Moreton Bay were symbiotic with *Comatula purpurea* (Müller) (AM 231), the specimens from Stradbroke Is. (AM 384) were from a "yellow crinoid" and the specimens from One Tree Is. (AM 394) were from a "lemon-yellow comatulid". The specimens from Western Australia were taken by dredge hauls as deep as 98 m. The specimens ranged in size from 15–34 mm, and the males were always smaller than the females.

Australian distribution: This species has not been reported before from Australia. The specimens from Western Australia were collected from Shark Bay and Bluff Pt. In eastern Australia they were taken from between the Capricorn Group and Moreton Bay.

General distribution: Indonesia, Malaysian Archipelago, Caroline, Marshall and Gilbert Islands.

OPPOSITE

Fig. 1 (see also fig. 2n).—*Synalpheus carinatus* (De Man). 34 mm female from AM. 394. a, b, Anterior region, dorsal and lateral view; c, d, large chela and merus, outer face; e, small cheliped, outer face; f, second leg; g, h, third leg and enlarged dactylus; i, telson. All figures except h, scale a., h, scale b.



a
b
f
g
c
h
i
d
e
5 mm
a
1 mm
b

Synalpheus tropidodactylus sp. nov.

Fig. 2

Holotype: 20 mm male from west of Geraldton. 28° 14′ S; 113° 14′ E. Dredged at 60 fathoms. (WM 90–65)

Paratype: 18 mm male from the same location.

Description: Anterior portion of carapace smooth except for rostral carina and slight depression between rostrum and orbital teeth; posterior to upper spine of basicerite and lateral to eyes carapace forming a lateral ridge that extends one-fourth the length of the carapace. Rostrum almost an equilateral triangle, with margins slightly concave, tip reaching almost to middle of second antennular article; slight rostral carina disappearing anterior to eyes. Ventral side of rostral base without orbitorostral process. Orbital teeth short, 0.2 as long as rostrum; not carinate.

Visible portion of first antennular article and second article subequal. Third article less than half as long as second article. Stylocerite reaching to end of first antennular article. Squamous portion of scaphocerite narrow, reaching to end of antennular peduncle, lateral spine a little longer. Carpocerite as long as antennular peduncle. Upper and lower teeth of basicerite almost parallel; with lower tooth longer than upper and reaching three-fourths length of first antennular article.

Large chela subcylindrical, 3.3 times as long as broad, with fingers occupying the distal 0.43. Small subacute tooth above dactylar articulation. Dactylus with "plunger" modified into sharp longitudinal ridge, and pollex with "socket" modified to form deep proximal "v"-shaped groove, open on distal end. Face of dactylus in opposition to pollex developed as sharp, thin cutting edge with crosses, like blades of a scissors, the corresponding sharp cutting edge of pollex. On pollex the proximal groove terminates on medial face as abrupt but rounded shoulder, while lateral margin of groove continues as the shearing blade; the rounded shoulder gives the appearance from inferior view of a twisting of distal half of fingers (fig. 2d). Carpus cup-shaped with acute tooth on distosuperior margin; tooth absent in paratype. Merus twice as long as broad; superior margin terminating in acute tooth; inferoexternal margin bearing strong tooth near mid-point, and an acute terminal tooth; inferointernal margin with distal obtuse tooth.

Small chela 4 times as long as broad; fingers a little more than one-third the total length. Carpus and merus similar to that of large chela; merus 3.4 times as long as broad.

Second leg with ratio of carpal articles 10:3:3:3:5.

Merus of third leg inermous, 4.6 times as long as broad. Carpus half as long as merus; superodistal margin projected, inferodistal margin bearing spine. Propodus as long as merus and bearing on inferior margin 14 spines with a pair distally. Dactylus biunguiculate with both ungui curved at right angles to axis of propodus. Superior unguis almost 3 times as long as inferior unguis.

Telson 2.6 times as long as posterior margin is broad. Posterior margin arcuate; spines on dorsal surface small and posterior to midline; terminal spines also small.

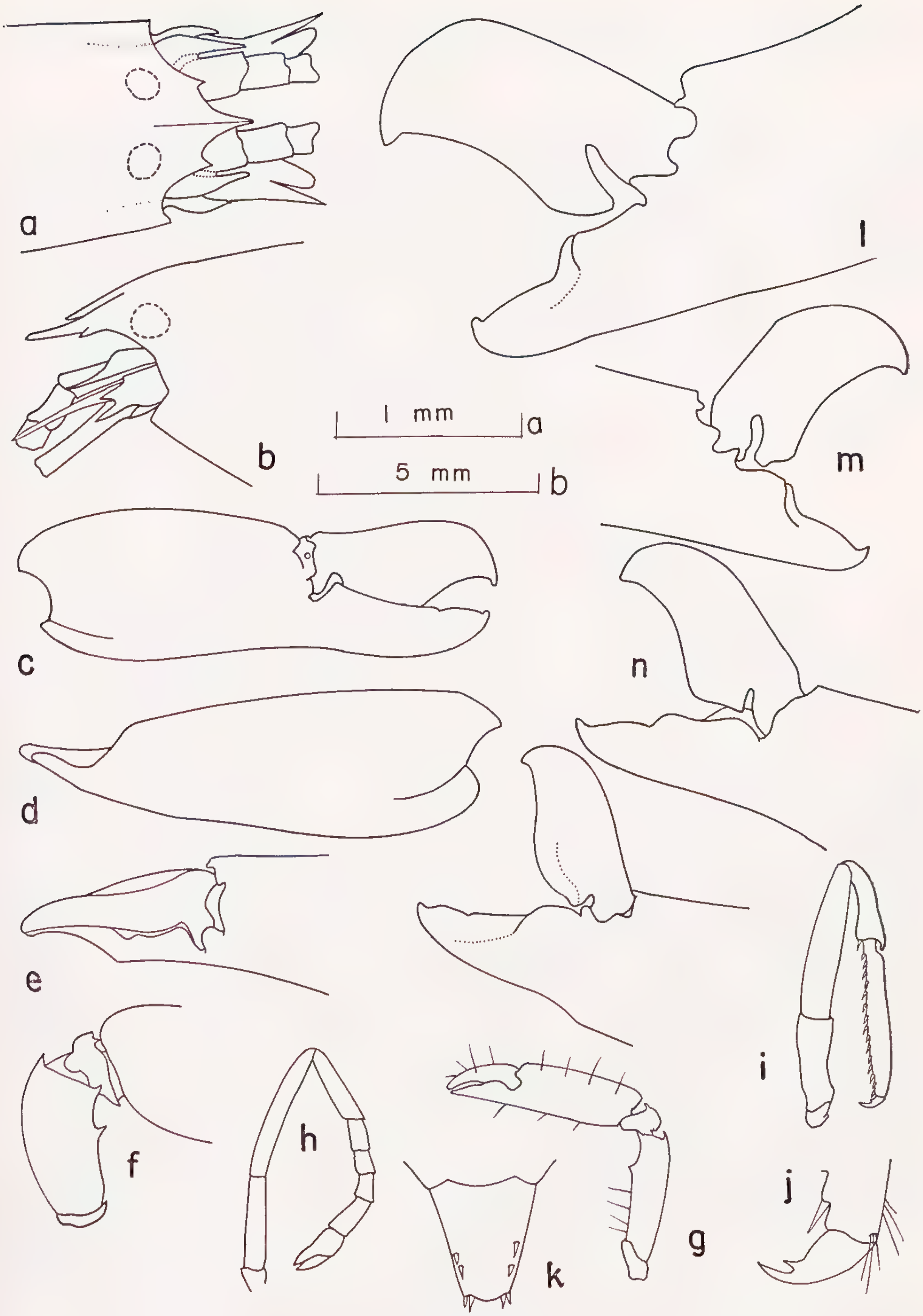


Fig. 2.—*Synalpheus tropidodactylus* sp. nov. Holotype. a, b, Anterior region of carapace, dorsal and lateral view; c, d, large chela, median and inferior aspect; e, distal end of large chela, superior aspect; f, merus large chela, inner face; g, small cheliped; h, second leg; i, j, third leg and dactylus; k, telson; l, distal region of chela of *S. comatularum;* m, distal region of chela of *S. stimpsoni;* n, distal region of chela of *S. carinatus;* o, distal region of chela of *S. tropidodactylus.* All figures except j, scale a; j, scale b.

Discussion: This species plainly belongs to the Comatularum group as it has the characteristic projection of the anterior portion of the carapace beyond the eyes and as it lacks the orbitorostral process.

The characteristics that separate this species and those of the Comatularum group known from Australia are given in Table 1. It may be separated from *S. odontophorus* De Man and *S. albatrossi* Coutière as from the Australian species by the development of the plunger of the dactylus of the large chela as a ridge. Other differences include the tooth on the base of the pollex of the large chela and the merus of the third legs in *S. odontophorus,* and the lack of a meral tooth on the large cheliped in *S. albatrossi.*

The name is derived from the Latin *tropido* or keel, and *dactylus,* and refers to the keel instead of a plunger on the large cheliped. The holotype and paratype have been placed at the Western Australian Museum.

Table 1. Australian Species of the Comatularum Group

Characteristic	*S. carinatus*	*S. tropido-dactylus*	*S. comatu-larum*	*S. stimpsoni*
Rostral carina continued past middle of carapace.	yes	no	yes	no
Orbital carinae sharp	yes	no	yes	no
Gastric region of carapace "humped"..	yes	no	yes	no
Length of orbital teeth to rostrum ..	0·4	0·2	0·3–0·5	0·3–0·5
Tooth on middle of margin of merus of large cheliped.	yes	yes	no	no
"Plunger" on dactylus of large cheliped	yes	no	yes	yes
Pollex of large chela appears twisted from inferior aspect.	no	yes	no	no
Sickle-shaped dactylus of small chela ..	no	no	yes	no
Terminal tooth on merus of third leg ..	no	no	yes	yes

Synalpheus comatularum (Haswell)

Fig. 3

Alpheus comatularum Haswell, 1882a, Proc. Linn. Soc. N.S.W. 6 (4): 762; reprinted in: 1882b, Cat. Austr. Stalk-eyed Crust. p. 189. Miers, 1884, Zool. Coll. H. M. S. Alert, p. 289 [redescription using Haswell's specimen].

Synalpheus comatularum Potts, 1915a, Proc. Camb. phil. Soc. biol. Sci. 18: 59, fig. 1; 1915b, Pap. Dep. mar. Biol. Carnegie Instn. Wash., 8: 76, pl. 1, fig. 1, text—figs 1c, 2d.

Synalpheus falcatus Bate, 1888, Challenger Rept. Zool. 24: 574, pl. 103.

Additional Australian records:

Ortmann, 1894, Denkschr. med. naturw. Ges. Jena, 8: 14. Thursday Is.
Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411. Torres Straits.
Balss, 1921, K. Svenska Vetensk.—Akad. Handl., 61 (10): 10. Cape Jaubert.
Clark, 1921, Bull. U.S. natn. Mus., 82, 1 (2): 624, pl. 38, fig. 1234, text fig. 943. Torres Straits.

Specimens examined: 2 specimens from AM 22; 11, AM 48; 2, AM 50; 2, AM 55; 6, AM 97; 4, AM 121; 2, AM 138; 1, AM 159; 1, AM 314; 2, AM 387; 1, AM 389; 3, AM 447; 1 specimen each from CS 29–32; 1, MM 86; 1, WM 33–65; 1, WM 34–65; 1, WM 37–65; 2, WM 44–65; 1, WM 115–65; 1, WM 122–65; 1, WM 128–65; 2, WM 190–65; 1, WM 220–65; 1, WM 274–65; 1, WM 305–65; 1, WM 4986; 2, WM 8972.

Diagnosis: Rostrum variable, tip reaching from near end of second to end of third antennular article and carrying knife-edged carina which extends to cardiac region where it terminates in a small oval depression; in lateral view rostral front depressed in relation to gastric region giving a "humped" appearance. Orbital teeth directed straight forward, dorsally rounded, not carinate, varying from one-third to one-half as long as rostrum. Anterior region of carapace between rostral base and orbital crests depressed as a deep groove. Posterior to upper spine of basicerite and lateral to orbital hoods carapace forming lateral ridges which extend one-fourth length of carapace. Pterygostomial angle strongly projecting at an acute angle but with tip rounded. Without orbitorostral process.

Visible part of first antennular article 1.5 times length of second article; third article a little shorter than second. Tip of stylocerite reaching from one-fourth length of second antennular article to end of that article. Scaphocerite with squamous portion narrow, reaching almost to end of antennular peduncle, lateral spine somewhat longer. Carpocerite reaching beyond antennular peduncle by length of third article. Lower spine of basicerite appreciably longer, upper spine slightly shorter than orbital teeth.

Large chela subcylindrical, 3 times as long as broad, with fingers occupying distal third. Palmar margin at articulation of dactylus with two acute teeth, one superior and one medial. Merus of large chela 2.7 times as long as broad, with superodistal angle projecting as acute tooth; inferior margins distally acute but not projecting.

Small chela 2.8 times as long as broad with fingers occupying distal 0.4. Dactylus crescentric, curving through 90° with acute hooked tip crossing and extending beyond fixed finger. Carpus hemispherical, bearing strong acute tooth on superodistal margin and a longer but more slender tooth on lower margin. Merus similar to that of large cheliped.

Carpal articles of the second legs with a ratio: 10:2:2:2:3.

Ischium of third legs less than 0.4 as long as merus, unarmed. Merus 6 times as long as broad, bearing acute tooth distally. Carpus 0.4 as long as merus, with superodistal margin projecting as a rounded tooth, inferodistal margin bearing short but heavy spine. Propodus slightly shorter than merus, inferior margin armed with two to several short spines. Dactylus strongly hooked with tip narrowly acute, inferior tooth reduced to mere right angle offset to the margin.

Telson 2.7 times as long as posterior margin is broad, posterior margin strongly arcuate, reaching almost half length of inner posterior spine. Spines on dorsal surface strong.

Discussion: The males are smaller than the females. The males can be readily recognized by the acute teeth on the posterior margins of the abdominal pleura. For the differences between *S. comatularum* and its closest relatives in Australian waters *see* Table I.

Biological notes: Of interest is Clark's account of the use of the peculiar adaptation of the small chela in its association with the crinoids. "The individuals were generally seated in pairs on the disc, but when slightly disturbed immediately dug the hook of this chela into the flesh of the disc, from which it was only dislodged with difficulty, or if the alpheid had left the surface of the disc the chela was serviceable for clasping the arm of its host. But this instrument is only used for temporary attachment, nor is it usually embedded in the host when the animal is at rest." (1921: 624.)

A number of authors, including Haswell and Potts, have supplied colour notes on this species, but Potts reported the colour varied with that of the host.

Eleven specimens from Broome (AM 48) were reported as symbiotic with *Comanthus timorensis* (J. Müller). (In Part I (p. 355) this species was listed as *Comanthus angulata;* it has since been changed to *C. timorensis*). Most of the specimens were from crinoids but many of the dredged specimens were not; possibly these had been torn loose from their natural association.

Australian distribution: In this collection are specimens from the West Coast of Australia from Busselton to Broome, on the east coast from the Torres Straits to Cape Grenville. The species had not been reported along the northern coast between Broome and the Torres Straits, nor south of Cape Grenville.

General distribution: Specimens have also been reported from Ceylon and Singapore.

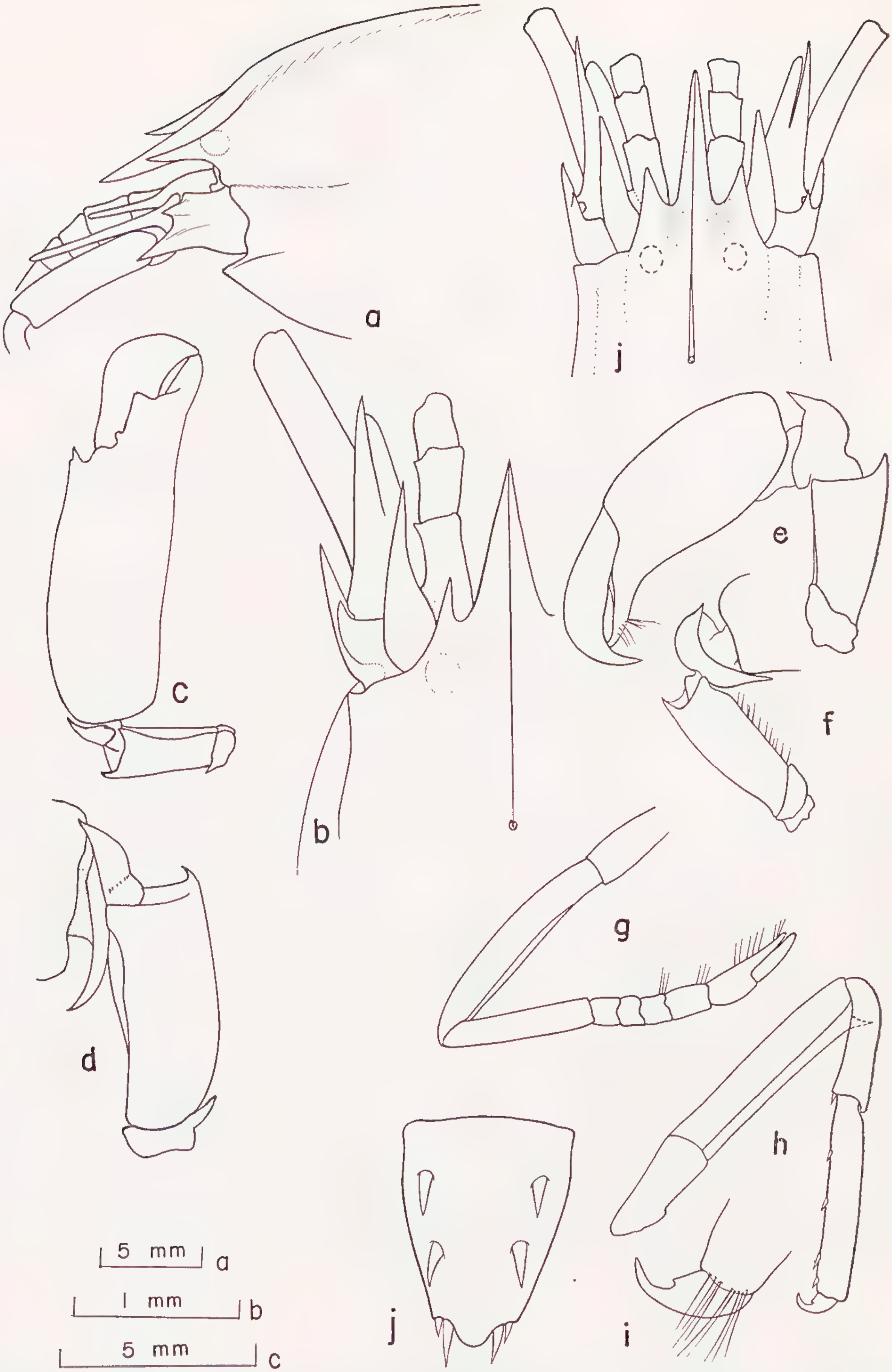


Fig. 3.—*Synalpheus comatularum* (Haswell). 30 mm male from AM. 48: a, b, anterior region of carapace, dorsal and lateral view; c, large cheliped, inner face; d, merus and carpus of large cheliped, outer face; e, f, small cheliped and merus, outer face; g, second leg; h, i, third leg and dactylus; j, telson. 25 mm female from AM. 48: j, anterior region, dorsal view. c, scale a; ı, scale b; a, b, d, e, f, g, h, k, j, scale c.

Synalpheus stimpsoni (de Man)

Fig. 2m, 4

Alpheus stimpsonii De Man, 1888a, Arch Naturgesch. 53 (1): 513, pl. 22, fig. 3.

Synalpheus stimpsoni Banner & Banner, 1966b. Siam Soc. Mono. 3, p. 46, fig. 12; 1968, Micronesica 4 (2): 274.

Alpheus amboinae Zehntner, 1894, Rev. Suisse Zool. 2: 202, pl. 8, fig. 23.

Synalpheus amboinae De Man, 1911, Siboga Exped. 39a[1] (2): 203, fig. 20; 1922, Siboga Exped. 39a[4] (5): 26, fig. 13. Banner, 1958, Pacif. Sci. 12 (2): 159, fig. 2.

Synalpheus consobrinus De Man, 1911, Siboga Exped. 39a[1] (2): 204, fig. 21.

Synalpheus brucei Potts, 1915b, Pap. Dep. Mar. Biol. Carnegie Instn. Wash. 8: 76, pl. 1, fig. 2, textfigs 1 a-b, 2 a-c, 3. Clark, 1921, Bull. U.S. natn. Mus. 82, 1 (2): 625.

Alpheus stimpsoni De Man var? Schenkel, 1902, Verh. naturf. Ges. Basel. 13: 567, pl. 13, fig. 22.

Synalpheus striatus Kubo, 1938, Annotnes. Zool. Jap. 17 (1): 89, textfigs. 1, 2. Miya, 1972, Publ. Amakusa Mar. Biol. Lab. Kyushu, 3 (1): 47, pl. 6.

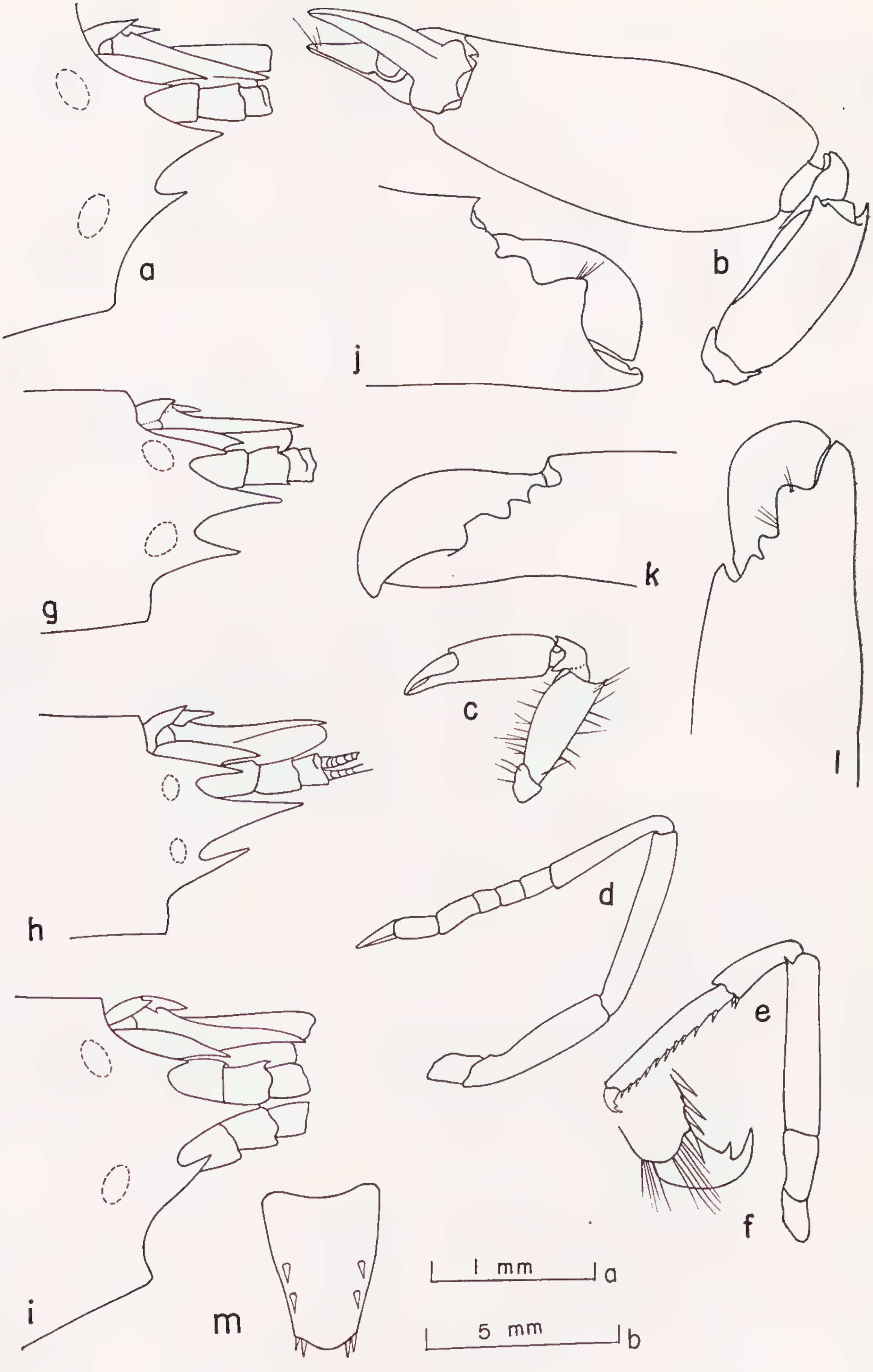
Additional Australian records: Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411. Torres Straits.

Specimens examined: 5 specimens from AC S1; 3, AC S5; 1 specimen each from AC 1, 3, 4, 7; 2 specimens each from AC 38, 39; 13, AM 22; 2, AM 35; 12, AM 48; 1, AM 52; 2, AM 57; 1, AM 85; 3, AM 97; 1, AM 139; 1, AM 177; 1, AM 192; 2, AM 231; 1, AM 239; 2, AM 394a; 1, AM 445; 1, AM 447; 1, AM 453; 2, BAU 11; 2, BAU 31; 2, JB2; 2, JB3; 3, JB4; 3, JB5; 3, WM 25–65; 1, WM 34–65; 1, WM 45–65; 1, WM 48–65; 1, WM 54–65; 1, WM 55–65; 1, WM 65–65; 1, WM 71–65; 5, WM 115–65; 2, WM 120–65; 1, WM 133–65; 1, WM 160–65; 1, WM 165–65; 1, WM 193–65; 1, WM 200–65; 2, WM 217–65; 1, WM 233–65; 1, WM 277–65; 2, WM 279–65; 3, WM 282–65.

Diagnosis: Rostrum reaching near end of second antennular article, with slight rounded carina reaching from tip to level of eyes. Orbitorostral grooves moderate, also disappearing at level of eyes. Orbital teeth with acute tips but not carinate, varying from one-third to more than one-half as long as rostrum. Carapace posterior to basicerite and lateral to eyes carrying rounded ridge that extends one-fourth length of carapace, similar to *S. comatularum* but not as strongly demarked. In lateral view rostral region of carapace depressed relative to gastric region. Without orbitorostral process.

OPPOSITE

Fig. 4 (see also fig. 2m).—*Synalpheus stimpsoni* (de Man). 30 mm female from AC S1: a, anterior region of carapace; b, large cheliped, superior aspect; c, small cheliped; d, second leg; e, f, third leg, dactylus enlarged; g, h, i, anterior region dorsal aspect of three different specimens; j, k, l, distal region of large chela of three different specimens; m, telson. All figures except f, scale a; f, scale b.


a
b
j
g
k
l
c
h
d
e
i
f
m
1 mm a
5 mm b

Relative lengths of antennular articles variable with first from slightly longer to almost twice length of second; third shorter than second. Stylocerite reaching to or slightly beyond end of first antennular article. Scaphocerite with broad squamous portion variable, reaching to about end of antennular peduncle, lateral spine a little longer, often curving inward. Carpocerite equal to lateral spine of scaphocerite. Inferior tooth of basicerite usually reaching near end of orbital teeth, superior spine much shorter.

Large chela varying from 2.5–3.6 times as long as broad; superior margin usually bearing tooth above dactylar articulation. Merus 2.6 times as long as broad, bearing distally a small subacute tooth on inferointernal margin and acute tooth on superior margin. Carpus cup-shaped, similar to *S. comatularum* with superodistal margin bearing a longer acute tooth.

Small chela 3.3 times as long as broad with fingers occupying distal 0.4. Dactylus slightly curved, of usual development. Carpus cup-shaped with distal teeth similar to those for large chela but greatly diminished. Merus 2.5 times as long as broad, bearing only small subacute tooth on superodistal margin; superior and both inferior margins bearing very fine setae.

Carpal articles of second leg with ratio: 10:2:2:2:3.

Merus of third leg 5 times as long as broad, armed with acute tooth distally. Carpus half as long as merus; superodistal margin projecting but rounded, inferodistal margin bearing a pair of short spinules. Propodus as long as merus, bearing on its lower margin numerous small spinules and a pair distally. Dactylus biunguiculate, 0.1 as long as propodus; ungui curved at right angles to the axis of the propodus, superior unguis slightly thicker at base and over twice as long as inferior.

Telson 2.2 times as long as broad at posterior end, anterior pair of spinules located just above middle, posterior pair slightly below middle.

Discussion: Five of the species of *Synalpheus* described as commensals on crinoids have been recognized as being closely related, but other species appear to be distinct. Each species in this group was described on the basis of a few specimens. De Man had only one ovigerous female from Amboina on which to base his species *S. stimpsoni*; eight specimens—two males, four females and two immature forms—from Indonesia for *S. consobrinus*; Zehntner had only one specimen of unspecified sex from Amboina for *S. amboinae*; Potts had seven females from the Torres Straits for the description of *S. brucei*; Kubo had one male and one ovigerous female from Japan for *S. striatus*. *S. stimpsoni* var(?) of Schenkel need not be formally considered, as it is not named and as it easily falls within the range of variation discussed below.

In a previous study (1968: 274) we placed *S. consobrinus* in synonymy under *S. stimpsoni*, the oldest name in this complex. In our present study collection we have eighty-nine specimens from eastern and western Australia (unfortunately none from the Torres Straits, the type locality for *S. brucei*) of which forty are intact. We have studied this group of forty in respect to twelve characteristics that have been used, or could have been used for differentiation of the species. The comparative data is presented in Table II; where possible the conditions reported were from the original texts, but at times the proportions were taken from figures.

Table 2. Nominal species reported in the S. stimpsoni *complex*

Characteristic	*S. stimpsoni*	*S. amboinae*	*S. brucei*	*S. striatus*	Australian specimens
Tip of rostrum to second antennular article.	To middle	Slightly past end.	To end	To end	From distal quarter of first to beyond end of second.
Length, orbital teeth to rostrum	0·3	Less than half	0·3	0·4	0·3–0·6.
Length, orbital teeth to first antennular article.	To middle	Past middle (de Man).	To middle.	To middle.	From middle almost to end.
Length, visible part first antennular article to following articles.	Longer than sum of following.	Equal to sum of following.	Same as *S. stimpsoni.*	Same as *S. amboinae.*	Length of first varying with angle it makes to carapace.
Tip of stylocerite to antennular article.	End first	Same	Same	0·3 of second	From shorter to definitely longer than first.
Relative length, teeth of basicerite.	Teeth subequal	Inferior markedly longer than superior.	Same as *S. amboinae.*	Same as *S. amboinae.*	Varying from condition in *S. stimpsoni* to condition in *S. amboinae.*
Length, carpocerite to antennular peduncle.	Reaching to end.	Same	Same	Same	A little shorter to a little longer than antennular peduncle.
Length/breadth merus, third leg	3·5 (from de Man).	2·8–3·6	3·5	4·0	3·2–4·1.
Length/breadth propodus, third leg.	5·6 (from plate).	4·4–5·2	Not figured or given.	6·5–7·0	4·7–6·0.
Spines of propodus third legs	7	9 (from plate)	Not given	7	6–10.
Size of outer angles, telson	Long	Short	Same as *S. fossor.*	Short.	From short to long.
Size of dorsal spines, telson	Large	Medium	Not given.	Small	From small to large.

From studying the material above we conclude that *S. stimpsoni* is a single but highly variable species and that those forms previously known as *S. stimpsoni* var?, *S. amboinae, S. brucei, S. striatus* as well as *S. consobrinus* are synonyms of *S. stimpsoni.*

We have compared our specimens of *S. stimpsoni* with De Man's type specimen of the closely related *S. odontophorus*, and with six specimens from the South China Sea which are presumably *S. odontophorus.* While both species appear to be variable, as yet there appears to be no overlapping of the characteristics that De Man used for separation; in addition we have found the orbital teeth to be much shorter in relation to the rostrum in *S. odontophorus* than in *S. stimpsoni.* We will discuss these specimens in a future paper.

Biological notes:

In Australia, as elsewhere, this species is commonly associated with crinoids, two being identified as *Comanthus purpurea* (Müller) (AM 231) and *Comanthus timorensis* (Müller) (AM 48), as well as numerous unidentified crinoids. Miya (1972) reported the species (as *S. striatus*) from three different species of crinoid and regarded it as an obligate commensal in Japanese waters. In addition it has been reported as occurring intertidally in heads of dead coral and under rocks, therefore in Australia it does not appear to be an obligate commensal. It has been dredged as deep as 25 fathoms.

The colour of those occurring on crinoids varies with the colour of the host. John Yaldwyn supplied colour notes for a specimen (AM 192) collected under rocks near Sydney: "Overall colour pale green, incipient darker green bands posteriorly on each abdominal segment; large hands with broad green "w" on white background. Through lens shortly after death: small, simple red chromatophores on body with background of granular blue chromatophores, possibly some yellow; details of chromatophores in green and white pattern could not be made out". As Potts (1915a: 77) remarked (*see* Appendix), longitudinal stripes against a translucent white or transparent background is a common colour pattern and was the basis of Kubo's name, *S. striatus.* The body length of our specimens ranged in size from 14–35 mm with the females larger than the males.

Australian distribution: This species is found from Sydney in temperate eastern Australia, northward along the Great Barrier Reef, across northern Australia and south as far as 37° S in Western Australia.

General distribution: Indonesia, Singapore, Thailand, Celebes, Philippines, Japan, Marshall and Gilbert Islands.

Synalpheus quadriarticulatus sp. nov.

Fig. 5

Holotype: 11 mm ovigerous female from sponge in 3 m water between Hammond and Waiwea Islands, Torres Straits (BAU 27).

Allotype: 10 mm male from same location as type.

Paratypes: 6 specimens, immature, 5–8 mm long, symbiotic with sponge from same location as type; 2 immature specimens 7 mm long from Thursday Is., Torres Straits (BAU 28).

Description: Rostrum and orbital teeth of equal length, orbital teeth broader at base, reaching more than one-third length of visible portion of first antennular article. Rostrum without orbitorostral process.

Second antennular article 0.8 as long as visible portion of first and 1.3 times as long as broad; third article 0.8 as long as second. Stylocerite reaching almost to end of first antennular article. Scaphocerite with squamous portion entirely lacking, curved lateral spine reaching past middle of third antennular article. Carpocerite 6 times as long as broad with tip reaching length of third antennular article past that article. Inferior spine of basicerite heavy, reaching to middle of second antennular article, superior spine pronounced and acute.

Large chela subcylindrical, 2.8 times as long as broad, distal end of superior margin of palm terminating in swollen tubercle from which projects an acute tooth. Superior margin of dactylus crescentric, almost circular, with inferior, or opposing, margin convex. Central portion slightly thickened, decreasing in thickness towards margins; tip projecting and rounded, overhanging end of pollex. Merus 2.6 times as long as broad. Both inferior margins distally armed with broad acute teeth, superior margin inermous.

Small chela about 3.5 times as long as broad, fingers a little shorter than palm. Fingers laterally broadened with opposing surfaces slightly excavate; both dactylus and pollex terminating in hooks; outer margin of dactylus finely serrate. Carpus cup-shaped, about a quarter as long as chela. Merus 5 times as long as broad, inermous; superior margin distally produced but rounded.

Carpal articles of second leg with a ratio: 10:2:2:4. Articles heavy, with third article 1.4 times as broad as long.

Merus of third leg 5.0 times as long as broad, inermous. Carpus 0.4 as long as merus, inferior margin terminating in spine, superior margin in obtuse tooth. Propodus 0.7 as long as merus, over 6 times as long as broad, bearing 5 inferior and 2 distal spines. Dactylus biungiuculate, gradually curved, superior unguis a little longer, but thinner, than inferior. Apex between ungui "U"-shaped.

Telson 3.5 times as long as posterior margin is broad, 2.7 times as broad anteriorly as posteriorly, lateral margin straight, posterior margin slightly arcuate, terminal spines prominent, outer pair about half the length of the inner. Outer uropod without distal articulation.

The type carried only two very large eggs with considerable amount of yolk and conspicuous eye spots.

Variation: There are certain pronounced differences between the smaller specimens which we regard as immature, and the holotype. In the holotype the rostrum and orbital teeth are nearly equal, while in the immature forms the rostrum is the longer. The antennules are more slender in the holotype and the stylocerite is longer in relation to the first antennular article. The lateral spine of the scaphocerite is longer in the paratype and the squame exists as a shoulder. The large chela is broader in the smaller specimens. The most important difference is in the small chela which in the holotype is more slender with its fingers as broad at the articulation as they are near the distal end, giving the appearance of a duck bill; the opposing surfaces of the fingers are flattened, not excavate. In the immature specimens the fingers taper slightly distally and the opposing surfaces are excavate. In the smaller specimens the carpal articles of the second leg are much broader than those of the type. Similarly all of the articles of the third leg are relatively broader. We believe these differences are due to different growth and that with the collection of more specimens the range will be bridged.

Discussion: Of the six species of *Synalpheus* with four articles in the carpus of the second leg, five are from the Western Atlantic: *S. filidigitus* Armstrong (1949: 15), *S. barahonensis* Armstrong (1949: 21), *S. rathbunae* Coutière (1909): 84), *S. longicarpus* (Herrick) (1891: 382), and *S. brooksi* Coutière (1909: 69); the Pacific species is *S. redactocarpus* Banner (1953: 29), known only from Hawaii. The present species differs from the six previously known by the broadened and flattened fingers of the small cheliped. This species also lacks the tufts of setae on the superior surface of the dactyl of the small chela which are typical of the Atlantic species. *S. redactocarpus* also lacks these tufts, but unlike *S. quadriarticulatus, S. redactocarpus* carries a well developed squame and lacks both the tooth above the dactylar articulation of the large chela, and the dorsal spinules on the telson. It should be noted that *S. longicarpus* and *S. brooksi* normally have five articles to the carpus, and Coutière (1909) attributes the reduction of articles in these species to immaturity; similarly, Miya (1972: 61) reported two immature males of *S. demani* Borradaile with only four carpal articles. Thus, the condition in *S. redactocarpus,* in which the type was only 5 mm in total length, may be due to immaturity, but the type specimens of *S. quadriarticulatus* are of fair size and are sexually mature.

In the general form of the anterior carapace, antennal and antennular bases, the form of the large and small chelae, third legs and uropods, this species closely resembles *S. pescadorensis* Coutière which is also found in Australian waters. It differs from *S. pescadorensis,* in addition to the conspicuous four articles of the carpus, by shorter basal antennular articles, a degenerate squame, slight differences in proportions of the third legs, the lack of a greatly developed tooth on the sympodite of the uropods, and in the lighter armature and more normal terminal margins of the telson (compare figs 5 and 6). In spite of these differences,

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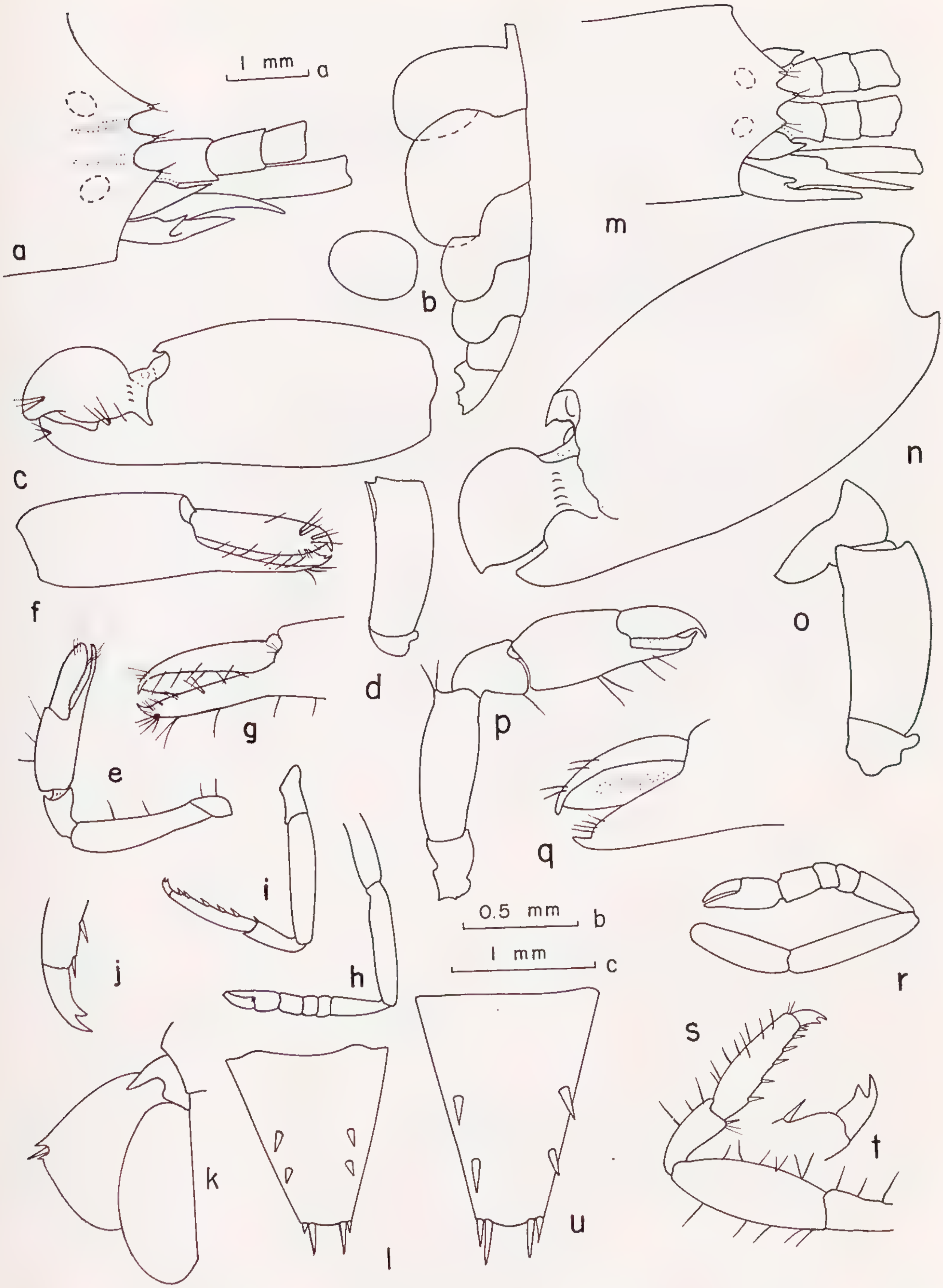
OPPOSITE

Fig. 5.—*Synalpheus quadriarticulatus* sp. nov. Holotype: a, Anterior region; b, abdomen and egg; c, d, large chela and merus; e, small cheliped, superior view; f, outer face of small chela; g, distal region, inner face of small chela; h, second leg; i, j, third leg and detail of dactylus; k, uropods; l, telson. Paratype: m, anterior region, dorsal view; n, o, large chela and merus; p, q, small cheliped, outer face and distal region enlarged, ventral view; r, second leg; s, t, third leg and detail of dactylus; u, telson. c, d, e, h, i, scale a; j, q, t, scale b; a, b, f, g, k, l, m, n, o, p, r, s, u, scale c.



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we feel the similarities are sufficiently great to suggest that *S. quadriarticulatus* may have evolved from *S. pescadorensis* and that the changes represent an adaption from an open life to that within the body of a sponge.

Mr Paul Jokiel of the Hawaii Institute of Marine Biology has given us a 10 mm specimen that he collected on Canton Is. in the Phoenix Archipelago on June 2, 1972; it came from a coral head from within the lagoon near the pass. It is quite similar in many characteristics to this species, and it has four articles to the carpus of the second legs, but there are several differences: it possesses a narrow squame that reaches to the end of the second antennular article; the rostrum and orbital teeth are reduced to shallow obtuse and rounded projections; the distal end of the palm of the large chela projects above the dactylus but does not carry an acute tooth; the small chela is the same as the immature Australian forms. It may be that this is a new but closely related species, but more specimens must be collected before a decision can be made.

Biological notes: These specimens were all collected from sponges that were lodged in the interstices of the base of dead coral heads. The large chela was more than half as long as the body of the shrimp and was markedly heavy for the size of the body. We have often noticed that alpheids that live in sponges seem to have a disproportionately large chela.

The name refers to the four carpal articles of the second leg. The holotype and allotype will be placed in the Australian Museum; the paratypes will be deposited at the Smithsonian Institution in Washington D.C.

Australian distribution: All specimens in the collection were taken in Torres Straits, north Queensland.

Synalpheus pescadorensis Coutière

Fig. 6

Synalpheus pescadorensis Coutière, 1905a. Fauna and Geog. Mald. and Laccad. 2 (4): 877, pl. 73, fig. 15. De Man, 1926, Mitt. zool. Mus. Berl. 12 (2): 341; 1911, Siboga Exped. 39a[1] (2): 298, fig. 63. Tiwari, 1963, Ann. Fac. Sci. Saigon, p. 279, fig 5.

Specimen examined: A 13 mm female from AME 3147.

Diagnosis: Rostrum reaching to first quarter of visible part of first antennular article. Orbital teeth equal in length to rostrum, but broader at base, almost equilateral triangles. Rostral base without orbitorostral process.

Visible part of first antennular article almost twice as long as second; second article 1.3 times as long as broad; third article only a little shorter than second. Stylocerite reaching to last quarter of first antennular article. Squamous portion of scaphocerite narrow, reaching to end of second antennular article, lateral spine as long as antennular peduncle. Carpocerite reaching the length of third article past that article. Basicerite with inferior tooth reaching past end of first antennular article; superior tooth prominent, almost half as long as inferior tooth.

Large chela subcylindrical, 2.3 times as long as broad. Termination of palm above dactylar articulation bearing swollen tubercle from which projects a smaller acute tooth; slightly medial is a low lobe with two setae. Pollex shorter than dactylus. Dactylus almost circular in outline, with superior margin crescentric, inferior or oppositional surface also strongly convex proximal to terminal tooth. Merus heavy, twice as long as broad, unarmed. Small chela 3 times as long as broad, fingers laterally broadened and excavate. Dactylus terminating in bifurcate tooth, pollex in single tooth; teeth meeting and crossing when chela is closed. Merus slender, 3.5 times as long as broad, also unarmed. Carpus cup-shaped, almost 0.3 as long as chela.

Carpal articles of second leg with ratio: 10:2:2:2:5 middle articles broader than long.

Third leg 3.5 times as long as broad, unarmed. Carpus 0.3 as long as merus, superodistal margin produced, inferior margin terminating in strong spine. Propodus 0.6 as long as merus, inferior margin bearing 8–9 spinules, one pair distally; superior margin somewhat bowed, and markedly broader in middle than proximally. Dactylus biunguiculate, superior unguis longer than inferior, nearly equal in breadth at base.

Telson 2.3 times as long as broad. Dorsal spines large, anterior pair shorter than posterior, posterior pair almost 0.3 length of telson. Terminal spines asymmetrical in the sole specimen with largest almost as long as posterior dorsal spine, other three about two-thirds the length of largest; smaller spines half as long as tip is broad. Posterior margins between spines very narrow and not produced. Sympodite of uropods with unusually long lateral tooth, half as long as external ramus. Outer uropod without articulation.

Discussion: Our specimen differs from Coutière's original specimen in that the squame is longer, reaching to end of second instead of the middle of the second antennular article. The orbital teeth on our specimen are acute rather than obtuse.

Further the dactyl of the small chela terminates in two distinct teeth in Coutière's specimen while in our specimen there is only one tooth that bears a small incision. The principle difference however, is in the posterior margin of the telson which in Coutière's, De Man's (1911), and Tiwari's (1963) specimens bear a slight rounded projection between the posterior pairs of spines. In this specimen, as well as De Man's from the Solomons (1926) the projection is lacking. Yet the Australian, like the other specimens, lack the articulation of the outer uropod and have the enlarged tooth of the sympodite. Therefore, tentatively we are leaving this specimen under Coutière's name.

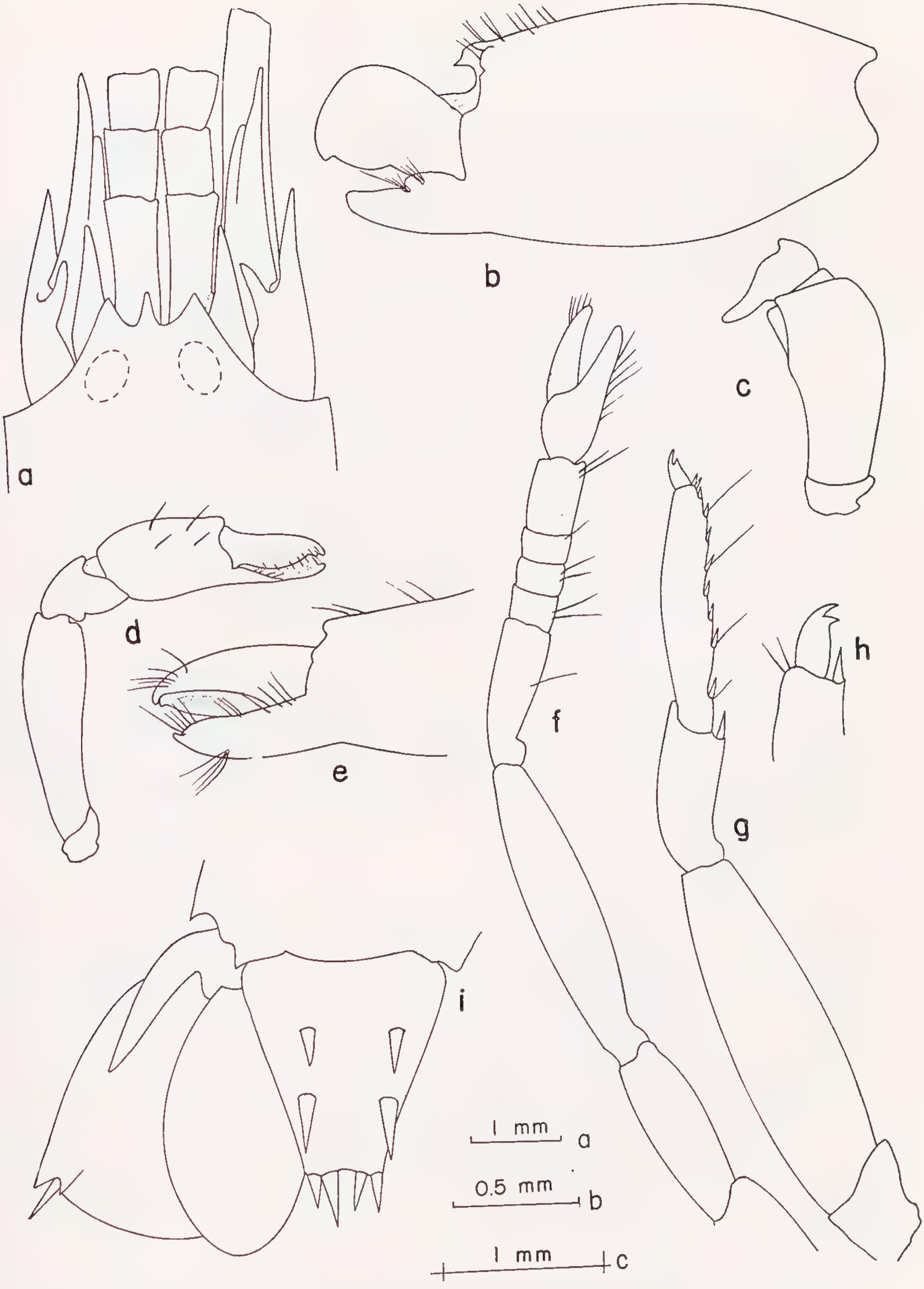
The broadened dactyl of the small chela shows relationship between *S. quadriarticulatus* (discussed above), *S. laticeps* Coutière and *S. antenor* De Man (the latter two not known from Australia). It can be separated from all three by large spines on the dorsal surface of the telson and the large tooth of the sympodite of the uropods.

Australian distribution: The only Australian specimen available was dredged from Keppel Bay in southern Queensland.

General distribution: This species is known from the Maldive Archipelago in the Indian Ocean and the Pacific from Vietnam, Indonesia, Sulu Archipelago, the Pescadores and the Solomon Islands.

OPPOSITE

Fig. 6.—*Synalpheus pescadorensis* Coutière. 13 mm female from AME 3174: a, Anterior region, dorsal view; b, c, large chela and merus; d, e, small cheliped and detail of anterior region in ventrolateral view; f, second leg; g, h, third leg and enlargement of dactylus; i, telson and uropods. b,c,d, scale a; h, scale b; a,e,f,g,i, scale c.


a
b
c
d
e
f
g
h
i
1 mm a
0.5 mm b
1 mm c

Synalpheus sciro sp. nov.

Fig. 7

Holotype: The sole specimen a 12 mm female from CSIRO station 208, 27° 40′ S; 113° 20′ E, northwest of Bluff Point, W.A., 10/10/63. Collected at 7 1/2 fathoms. (WM 64–65).

Description: Rostral tip reaching to well past middle of visible part of first antennular article, slightly upturned, margins concave. Orbital teeth nearly as long as rostrum, but broader at base. Tips of rostrum and orbital teeth rounded and bearing a few setae. Dorsal surface of carapace flat except for slight orbito-rostral grooves that extend only part way to corneas. Corneas lying length of first antennular article posterior to orbitorostral indentation; pigmented area of eyes small. Rostral base without orbitorostral process.

Visible portion of first antennular article 1.6 times length of second; second article a little longer than broad; third article slightly shorter than second. Stylocerite reaching to middle of visible part of first antennular article on one side and to first quarter on other (probably the longer stylocerite is normal). Scaphocerite with narrow squamous portion reaching almost to end of third antennular article; lateral spine reaching length of third article past that article. Carpocerite slender, 6.5 times as long as broad when viewed ventrally, reaching just past end of lateral spine of scaphocerite. Inferior spine of basicerite reaching to first third of second antennular article; superior spine strong, equal to stylocerite.

Large cheliped missing.

Small cheliped with fingers excavate and denticulate. Pollex with three teeth distally, middle tooth the strongest, dactylus with two teeth displaced slightly medially. Chela 3 times as long as broad, fingers about 0.8 length of palm. Carpus cup-shaped, 0.3 as long as chela. Merus slender, 3 times as long as broad with inferodistal margins inermous, superodistal margin projecting as a small acute tooth carrying several hairs.

Carpal articles of the second leg with a ratio 10:1:1:1:5; middle articles broader than long.

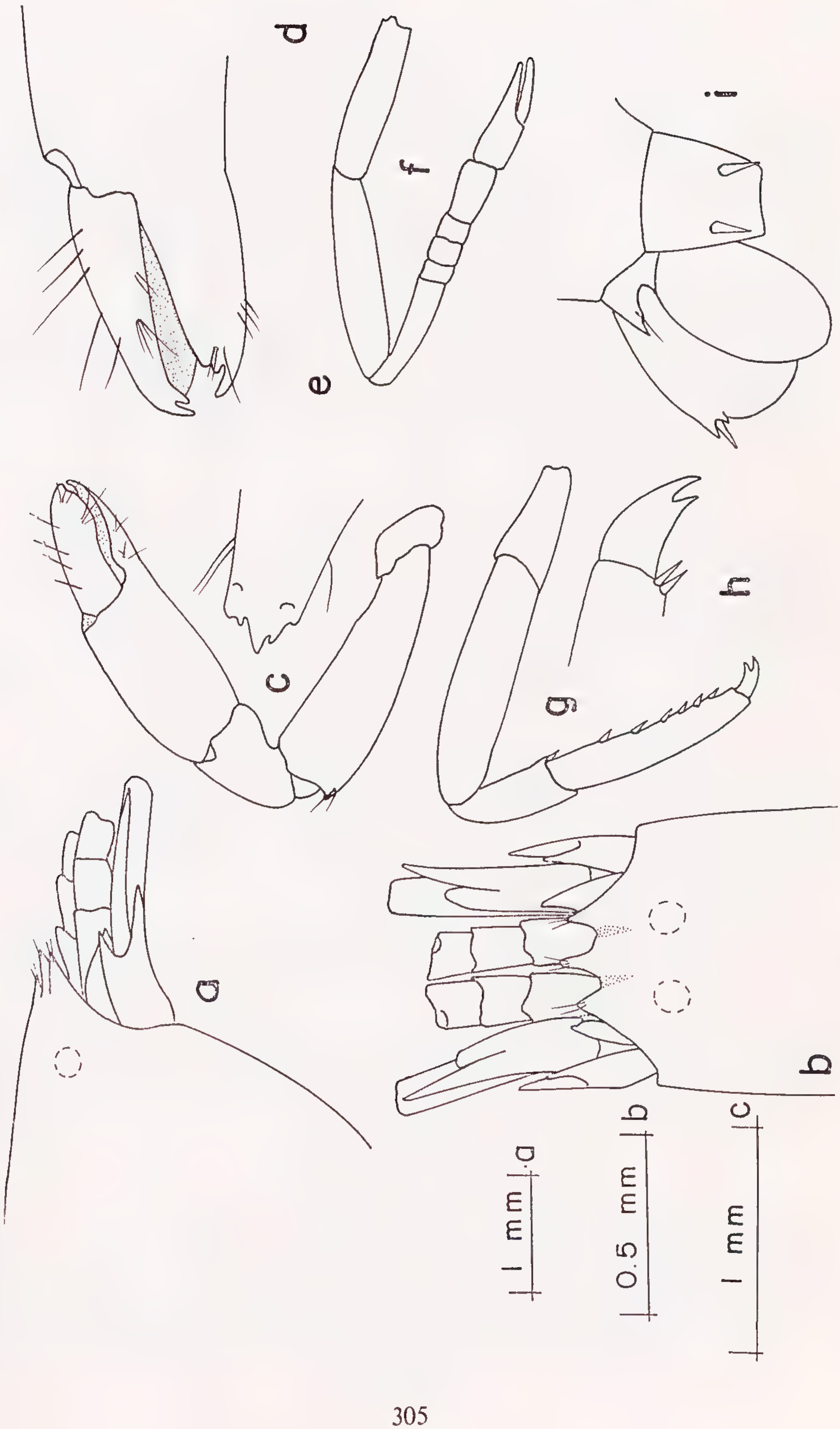
Merus of third leg 4 times as long as broad, unarmed; carpus 0.4 as long as merus, inferodistal margin bearing small spine, superodistal angle projecting as rounded tooth. Propodus 0.7 as long as merus, bearing on its inferior margin 7 spines and 2 distally. Dactylus biunguiculate, inferior unguis slightly shorter; apex between the notch subacute.

Telsal tip mutilated. Outer uropod without distal articulation.

Discussion: The long anterior extension of the carapace beyond the eyes, the lack of orbitorostral projection and even the form of the ungui of the third legs is similar to the species in the Comatularum group, but none of these have the spatulate and denticulate dactylus on the small chela. On the other hand, of

OPPOSITE

Fig. 7.—*Synalpheus sciro* sp. nov. Holotype. a, b, anterior region, dorsal and lateral aspects; c, small cheliped, outer face; d, inner face of distal region of small chela; e, detail of fingers of small chela, ventral aspect; f, second leg; g, h, third leg and enlarged view of dactylus; i, telson and uropods. a, b, c, f, g, i, scale a; h, scale b; d, e, scale c.



a
b
c
d
e
f
g
h
i
1 mm a
0.5 mm b
1 mm c

those with the subspatulate dactylus only *S. pescadorensis* and *S. quadriarticulatus* lack the orbitorostral process; these species also lack the distal articulation of the uropod. This species has the normal number of carpal articles on the second leg; *S. quadriarticulatus* has only four. In *S. pescadorensis* the front of the carapace does not project, and the rostrum is markedly shorter than the first antennular article, the stylocerite and even the superior spine of the basicerite, while in *S. sciro* the rostrum is over half the length of the visible portion of the first antennular article almost as long as the longer (normal?) stylocerite and about equal to the superior spine of the basicerite. The most marked difference between the two species, however, lies in the tooth of the sympodite of the uropods which is half as long as the outer uropod in *S. pescadorensis*, and is less than a quarter the length of the uropod in *S. sciro*.

The name is derived from an anagram of CSIRO, the commonly used abbreviation for Commonwealth Scientific and Industrial Research Organization of Australia, the agency that has loaned many of the specimens for this study. The holotype will be deposited at the Western Australian Museum.

Synalpheus bituberculatus De Man

Fig. 8

Synalpheus bituberculatus De Man, 1910b, Tijdschr. ned. dierk. Vereen, 11 (4): 294; 1911, Siboga Exped. 39a[1] (2): 276, fig. 53. Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 66, fig. 22. Miya, 1972, Publ. Amakusa Mar. Biol. Lab. 3 (1): 57, pl. 10.

Specimens examined: 2 specimens from AM 21; 1, AM 90; 1, AM 334; 1, BAU 10; 7, BAU 25; 9, BAU 27; 8, BAU 28; 2, BAU 30; 1, BAU 37; 1, BAU 38; 1, BAU 40; 1, BAU 42; 1, BAU 43; 10, BAU 44; 4, BAU 48; 2, BAU 56; 2, BAU 57; 1, WM 166–65.

Diagnosis: Rostrum with tip upturned, rounded to acute, sides parallel to triangular; tip reaching to near middle of visible part of first antennular article. Orbital teeth almost as long as rostrum, but broader at base, with several setae at tips. Rostral base with orbitorostral process.

Second antennular article 1.6 times as long as wide, a little shorter than visible part of first antennular article and a little longer than third article. Stylocerite heavy, reaching to proximal portion of second article. Scaphocerite with squamous portion narrow, reaching to near end of antennular peduncles; lateral margin concave, lateral spine varying in length from end of antennular peduncle to as long as carpocerite. Carpocerite slender, 6.0 times as long as broad, reaching length of third article past that article. Superior tooth of basicerite acute, short; inferior tooth acute, longer than stylocerite.

Large chela cylindrical, 2.3 times as long as wide with fingers occupying distal 0.3. Palm usually terminating above dactylar articulation in two conical, obtuse tubercles, tubercles directed forward and upward. Superior margin of dactylus sharply carinate. Merus twice as long as broad, with superior margin strongly curved, inferointernal and superior margins terminating in acute teeth.

Small chela 2.8 times as long as broad. Dactylus proximally broad, tapering slightly towards tip; tip with one distal and one medial tooth. Pollex with strong terminal tooth, at times with a small secondary tooth. When fingers are closed the major tooth of pollex does not appear to fit between teeth of dactylus. Dactylus, pollex and lower side of palm bearing many setae. Inferointernal edge of carpus bearing a few slender spines. Merus almost 4 times as long as broad distally; inferoexternal margin bearing closely spaced fine long setae; inferointernal margin bearing 6–9 slender spines, shorter than the setae on the external margin.

Carpal article of the second leg with a ratio: 10:2:2:2:4.

Merus of third leg 3 times as long as broad, bearing on its inferointernal margin 6–9, or at times less, short strong spines, but without distal teeth or spines. Carpus 0.4 as long as merus, superior margin projecting as tooth, inferior margin bearing strong distal spine. Propodus 0.7 as long as merus, inferior margin bearing 6–10 spines. Dactylus biunguiculate, ungui almost equal at base but with superior unguis about twice as long as inferior. Merus of fourth leg inermous.

Telson 3 times as long as posterior margin is wide; posterior lateral corners angular but not projecting. Outer uropod with transverse articulation. First pair of dorsal spinules located slightly anterior to middle, second pair slightly posterior.

Discussion: We studied the variation in thirty specimens from Australia and twenty-nine from the Philippines; also, through the courtesy of the Zoölogisch Museum in Amsterdam we were able to study the holotype and several paratypes of De Man. We found variation in the frontal region similar to that illustrated by De Man (1911: pl. 11, figs. 53, 53a and 53b; *cf.* our fig. 8a and i). However, we found a range of variation greater than that reported by De Man in a number of characteristics:

1. The spine of the scaphocerite varied from as long as the antennular peduncle to as long as the carpocerite.
2. The two well-developed teeth above the dactylar articulation on the large chela in a few specimens were reduced to a single slight protrusion that could be seen only by rotation of the chela in a light arranged to shadow the irregularity, but these slight knobs were marked by the characteristic setae (the specimen from BAU 42 lacked all traces of the teeth and the setae, but could be identified by the characteristic slender spines on the merus of the large cheliped).
3. The acute tooth on the apex of the superior margin of the merus of the large chela varied in development, and in a few was missing entirely.

However, the shape and the armature of the small chela remained quite constant. De Man had not described the few spines on the carpus and merus of this appendage, yet we found it to be consistent in his type series, in the present collections and in the specimens we previously reported from Thailand (1966b). In a few specimens the spines appear to have been broken off.

Three specimens collected from Darwin (BAU 57) bear only 1–2 spines on the inferior margin of the third legs (fig. 8p) instead of the 5–6 carried by all other specimens; coupled with this is a lesser development of the two tubercles above the dactylar articulation, with the lateral tubercle less well developed than the medial. This may represent a distinct geographical subspecies, but we are loathe to erect one for so few specimens in a variable species.

We have also three specimens in which the dactyl of the large chela is curved slightly inward, giving the chela a twisted look. We also found this condition in Thai specimens (*loc. cit.*). We attach no significance to this variation.

De Man recognized this species to be closely related to *S. pachymeris* Coutière (originally described as *S. biunguiculatus pachymeris* 1905a: 873, and raised to specific rank by De Man, 1911: 199). He separated the two species by the tubercles above the dactylar articulation of the large chela, by breadth of the meri of both chelipeds, by the relative lengths of the scaphocerites. As we found these characteristics variable we had considerable doubt about the separation of

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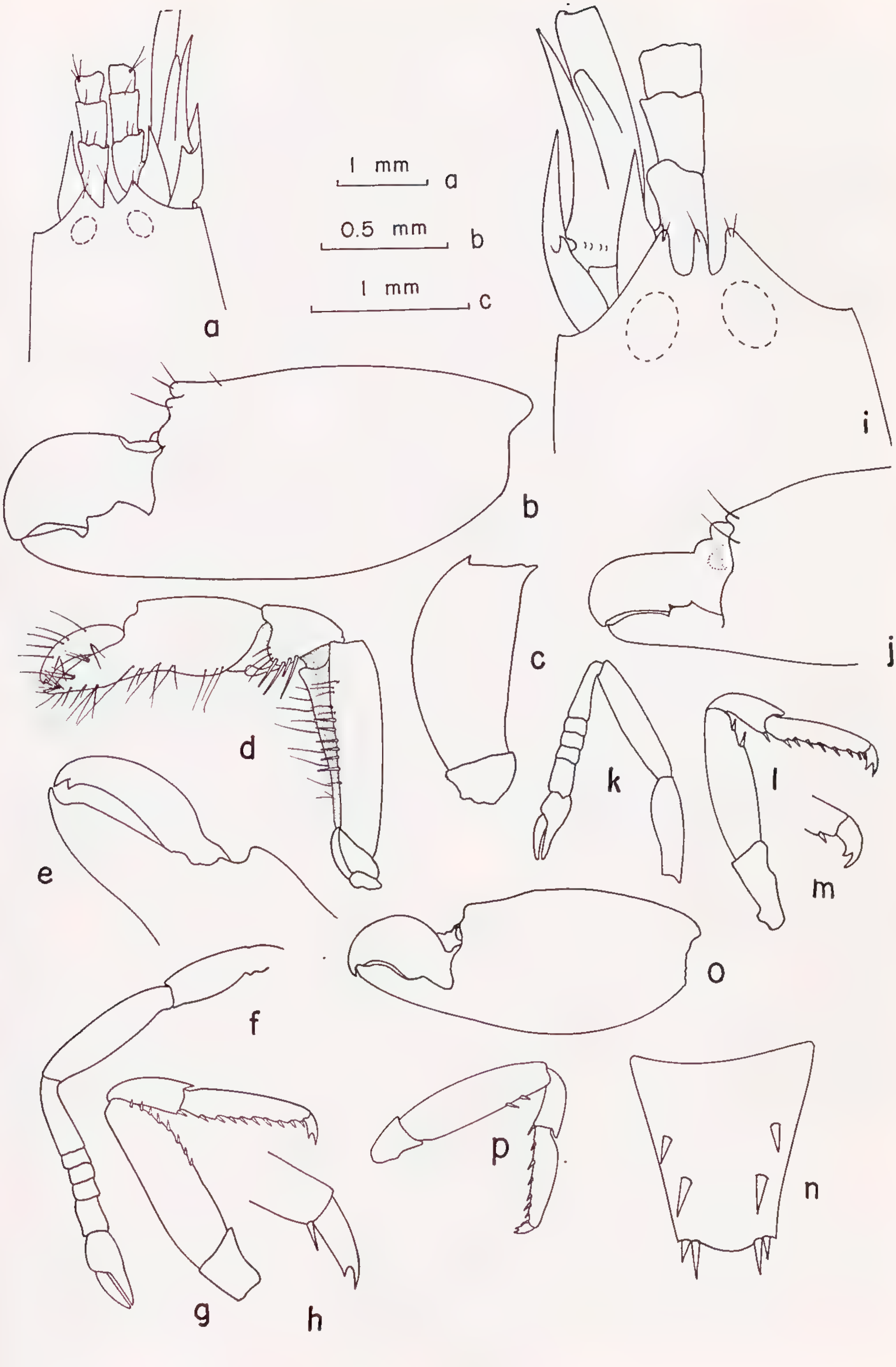
OPPOSITE

Fig. 8.—*Synalpheus bituberculatus* De Man. 16 mm female from BAU 27: a, anterior region, dorsal view; b, c, large chela, outer face and merus, inner face; d, e, small cheliped, inner face and enlarged dactylus; f, second leg; g, h, third leg and enlarged dactylus. 11 mm male from AM. 334: i, anterior region, dorsal view; j, distal region of large chela; k, second leg; l, m, third leg and enlarged dactylus; n, telson. Specimen from BAU 42: o, large chela. Specimen from BAU 57: p, third leg. a, b, c, d, f, g, j, o, scale a; h, m, scale b; e, i, k, l, n, p, scale c.



1 mm a
0.5 mm b
1 mm c
a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p

the species. Through the courtesy of the Museé d'Histoire Naturelle of Paris we were able to examine the specimens that Coutière had reported from Cargados and Providence Islands (1921: 417) and now believe that the two species may be firmly separated by the nature of the small chela. In *S. bituberculatus* the dactyl of the small chela is slightly broadened and bears a distal tooth with an accessory tooth medially, while in *S. pachymeris* the tip is tapered and without the accessory tooth; further, on the merus of *S. bituberculatus* the inferoexternal margin bears a row of long fine setae, the inferointernal a series of slender spines, while *S. pachymeris* bears only scattered setae on the merus. While the relative length of the scaphocerite cannot always be relied upon, it is usually definitely longer than the antennular peduncle in *S. bituberculatus* and definitely shorter in *S. pachymeris*. Similarly, on the large cheliped the superior margin of the merus is usually produced into an acute tooth and the palm usually bears the two upturned tubercles in *S. bituberculatus* while in *S. pachymeris* the meral tooth is always lacking and there is never more than one tubercle which is always directed forward.

No specimens resembling *S. pachymeris* have been found in the Australian collections. While it is incidental to the present study we suggest that if anyone collects specimens similar to the form that Coutière named "variété *cargadosi*" (1921: 417), he carefully consider its specific separation from *pachymeris* (or, as Coutière described it, *S. biunguiculatus*), for the characteristics used to separate it do not fall into the range of variation we have seen.

Biological notes: *S. bituberculatus* is commonly found in sponges, living in pairs. We have also found it in dead coral from all sections of the reef in waters up to 8 metres deep. De Man reported it from sandy bottom at 36 metres. A colour note by John Yaldwyn with the specimen from One Tree Island (AM 334) states "body and appendages pinkish transparent with scattering of red chromatophores; eyes black, fingers orange". Our specimens ranged in size from 10–20 mm.

Australian distribution: This species was collected in Western Australia in the Houtman Abrohlos; in northern Australia from Darwin and the Torres Straits; and in eastern Australia from Green Island, Hayman Island and in the Swain Reefs-Capricorn Group area.

General distribution: Indian Ocean, Singapore, Thailand, Indonesia, Japan, Philippines*.

Synalpheus harpagatrus sp nov.

Fig. 9

Holotype: 38 mm female from sponge in 50 feet of water 5 miles west of North Beach, Perth, Western Australia (WM 86–65) collected by D. Blair, 9/9/61.

Allotype: 28 mm male from a pair taken from a sponge. Cottesloe, near Perth, Western Australia (WM 11129/30) collected by L. Glauert, December, 1924.

Paratypes: 1, 35 mm female from WM 11129/30; 1, 14 mm male and 1, 20 mm female from WM 10380; 1, 14 mm female from WM 4985; 1, 25 mm male from SM 1.

Description: Rostrum awl-shaped, three times as long as broad at base, tip three-quarters length of visible part of first antennular article. Orbital teeth triangular, about two-thirds as broad at the base as long, with inner margin straight and parallel to axis of rostrum. Tips of rostrum and orbital teeth bearing a few setae. Rostral base with orbitorostral process.

Second antennular article 0.8 as long as visible part of first, and 1.5 times as long as wide. Third article a little shorter than second. Stylocerite acute, reaching middle of second antennular article. Lateral tooth of scaphocerite reaching near end of third antennular article. Squamous portion narrow, reaching near middle of third antennular article. Carpocerite a little more than six times as long as broad and reaching well past end of antennular peduncle. Inferior tooth of basicerite almost as long as stylocerite, superior tooth acute, slender, about one-third as long as inferior tooth. Distal end of ultimate article of third maxilliped bearing a cluster of 10–12 short heavy spines.

Large chela sub-cylindrical, 2.4 times as long as broad with fingers occupying distal 0.3. Distal end of superior margin of palm slightly protruding and bearing medially a small acute tooth. Merus thick, 1.8 times as long as broad, inferior margins inermous, but bearing on superodistal margin an acute triangular tooth.

Small cheliped stout. Chela nearly cylindrical, 2.3 times as long as broad, fingers a little less than half as long as palm. Dactylus broadened with rounded tip bearing 4 rounded obtuse teeth. Pollex also broadened, tip bearing 3 triangular acute teeth. Distal half of opposing surfaces of pollex and dactylus deeply excavate, proximal half of pollex convex and fitting into corresponding cavity on dactylus. When fingers are closed, teeth at tip of dactylus mesh with, but extend beyond, those of fixed finger. Carpus cup-shaped, superodistal margin armed towards medial side with a subacute tooth similar to that of large chela. Merus heavy, 1.8 times as long as broad, with superodistal tooth similar to that of large chela.

Carpal articles of second leg with a ratio: 10:1.8:1.8:1.8:4.0.

Merus of third leg 3.2 times as long as broad, bearing on inferointernal margin 5 strong spines, but none distally. Carpus one-third as long as merus, superodistal margin projecting as strong obtuse tooth, inferodistal margin bearing two spines. Propodus about two-thirds length of merus, bearing on its inferior margin 5 strong spines, but none distally. Carpus one-third as long as merus, superodistal margin projecting as strong obtuse tooth, inferodistal margin bearing two spines.

Propodus about two-thirds length of merus, bearing on its inferior margin seven spines and two distally. Dactylus biunguiculate with ungui equal in length; superior unguis 4 times as long as broad at base and following gradual curve of dactylus; inferior unguis about as long as broad at base and at almost a right angle to the axis of propodus. Fourth leg similar to third, but bearing less spinules on merus. Fifth leg without spines on merus.

Telson 1.8 times as long as broad at posterior margin, much shorter than uropods. Posterolateral angles acute and slightly projected. Posterior margin broadly arcuate. Outer uropod with transverse articulation.

Discussion: On the small cheliped of the male allotype the merus was more slender than that of the holotype, the inferodistal tooth was merely a rounded prominence and the small tooth on the superodistal margin of the carpus was absent. However, as another male we examined had a small cheliped that was like that of the holotype, we feel this must be an individual variation. In two specimens the rostrum and orbital teeth are a little longer in relation to the first antennular article than those of the holotype.

This species appears to be related to the Indo-Pacific group of synalpheids that carry broadened and often denticulate fingers on the small chela. The species in the American Gambarelloides (= Laevimanus) group have similarly developed fingers, but according to Coutière (1909, *serratum*) the "Laevimanus" group always has a heavy crest or brush of setae on this dactylus which never appears in the Indo-Pacific forms. The Indo-Pacific group of species include those listed in the key from couplets 6 to 12 (p. 279) and *S. antenor* De Man and *S. laticeps* Coutière. From all these species *S. harpagatrus* is separated by the presence of strong spines on the merus of the third legs and by the very heavy spines on the tip of the third maxilliped. Other characteristics useful for the separation of this species are given in the key.

The specific name is derived from *harpatus* Gr., seizing or holding and *–tros*, Gr., tool or instrument, and refers to the possible use of the small chela in the cavity of the host sponge.

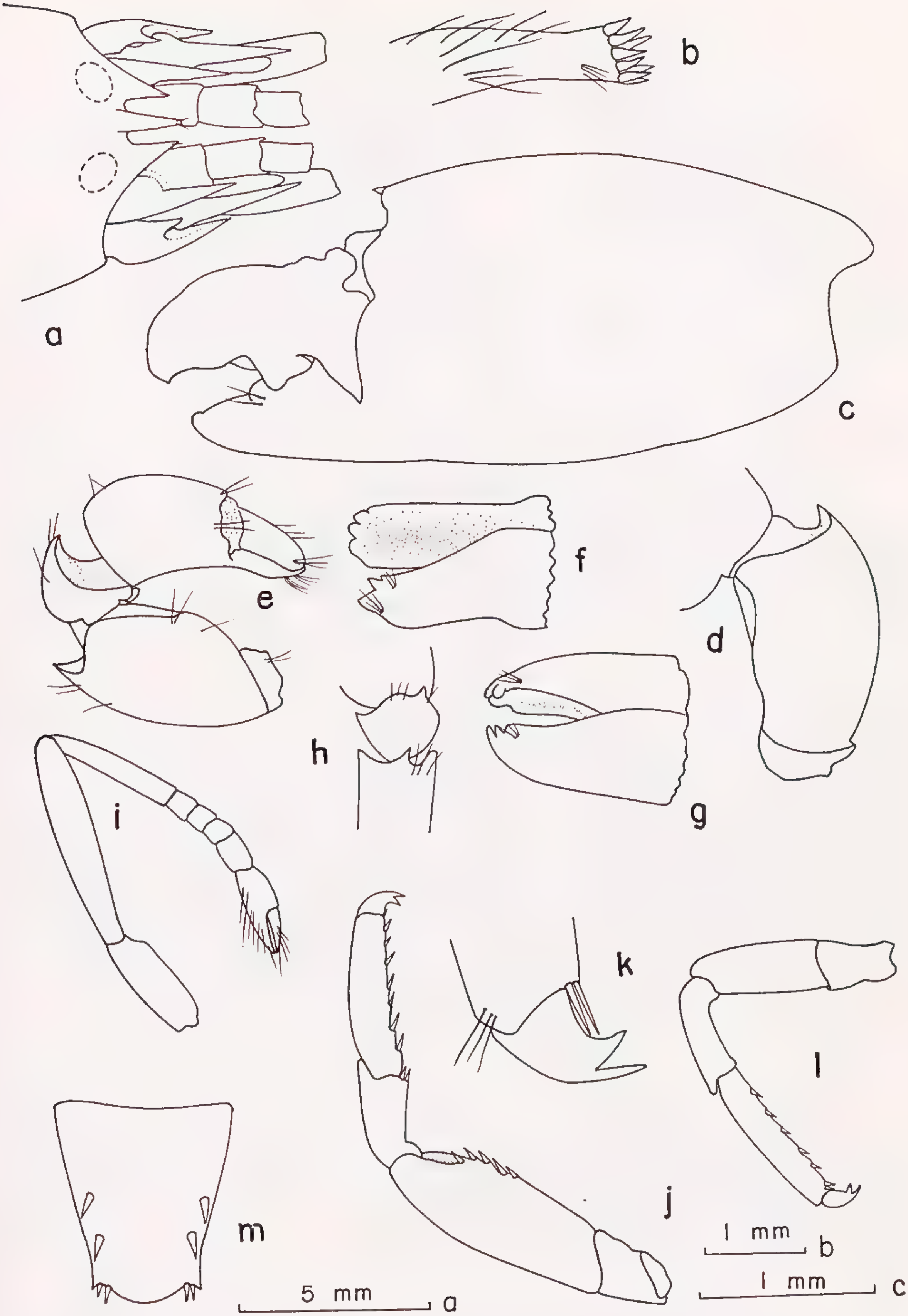
The holotype and allotype will be placed in the Western Australian Museum in Perth.

Biological notes: All of the specimens came from sponges except one that was dredged, but it might have been separated from a sponge in the dredging process. The type was dredged from 50 ft, but all except one of the paratypes were collected from sponges intertidally.

Australian distribution: All specimens with locality data were collected between Fremantle and Geraldton, W.A. A 30 mm male collected by W. Greenwood, August 30, 1909, had no collection data, but as it came from the South Australian Museum, we presume it may have been collected from South Australian waters.

OPPOSITE

Fig. 9.—*Synalpheus harpagatrus* sp. nov. Holotype. a, anterior region, dorsal view; b, distal end of third maxilliped; c, d, large chela and merus, outer face; e, small cheliped; f, g, dactyl and pollex of small chela, ventral and lateral view; h, superior face of carpus and distosuperior section of merus of small cheliped; i, second leg; j, k, third leg and dactylus; l, fifth leg; m, telson. c, d, e, h, i, j, l, m, scale a; a, f, g, scale b; b, k, scale c



a
b
c
d
e
f
g
h
i
j
k
l
m
5 mm a
1 mm b
1 mm c

Synalpheus theano De Man

Fig. 10

Synalpheus theano De Man, 1910b, Tijdschr. ned. dierk. Vereen 11 (4): 296; 1911, Siboga Exped. 39a[1] (2): 293, fig. 61. Banner & Banner, 1972, Crustaceana 23 (1): 20, fig. 3f [separation from *S. neptunus* (Dana)].

Nec Synalpheus theano Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 69, fig. 24 (= *S. neptunus*).

Specimens examined: 1 specimen from AM 140; 9, AM P 13556; 8, BAU 27; 6, BAU 28; 1, BAU 40; 1, BAU 43; 1 specimen each from CS 2, 10, 15, 16, 17, 23; 2, QM W 1053; 2, UQ 22; 1, WM 268–65; 1, WM 10380; 2, WM 10487; 1, WM 10591/92.

Diagnosis: Rostrum reaching past middle of first antennular article; orbital teeth as long as rostrum, but broader at base. Rostral base with orbitorostral process.

Antennular articles subequal, second article 1.3 times as long as broad. Stylocerite reaching from three-fourths length of first antennular article to end. Lateral spine of scaphocerite reaching from one-half length to end of third article; squamous portion reaching variously from three-fourths the length, to end, of second article. Carpocerite reaching almost the length of third antennular article past that article. Inferior spine of basicerite varying from one-half the length of the second article to end; superior angle rounded.

Middle article of third maxilliped bearing two strong spines in addition to setae, tip of final article bearing a dense tuft of setae but no spines.

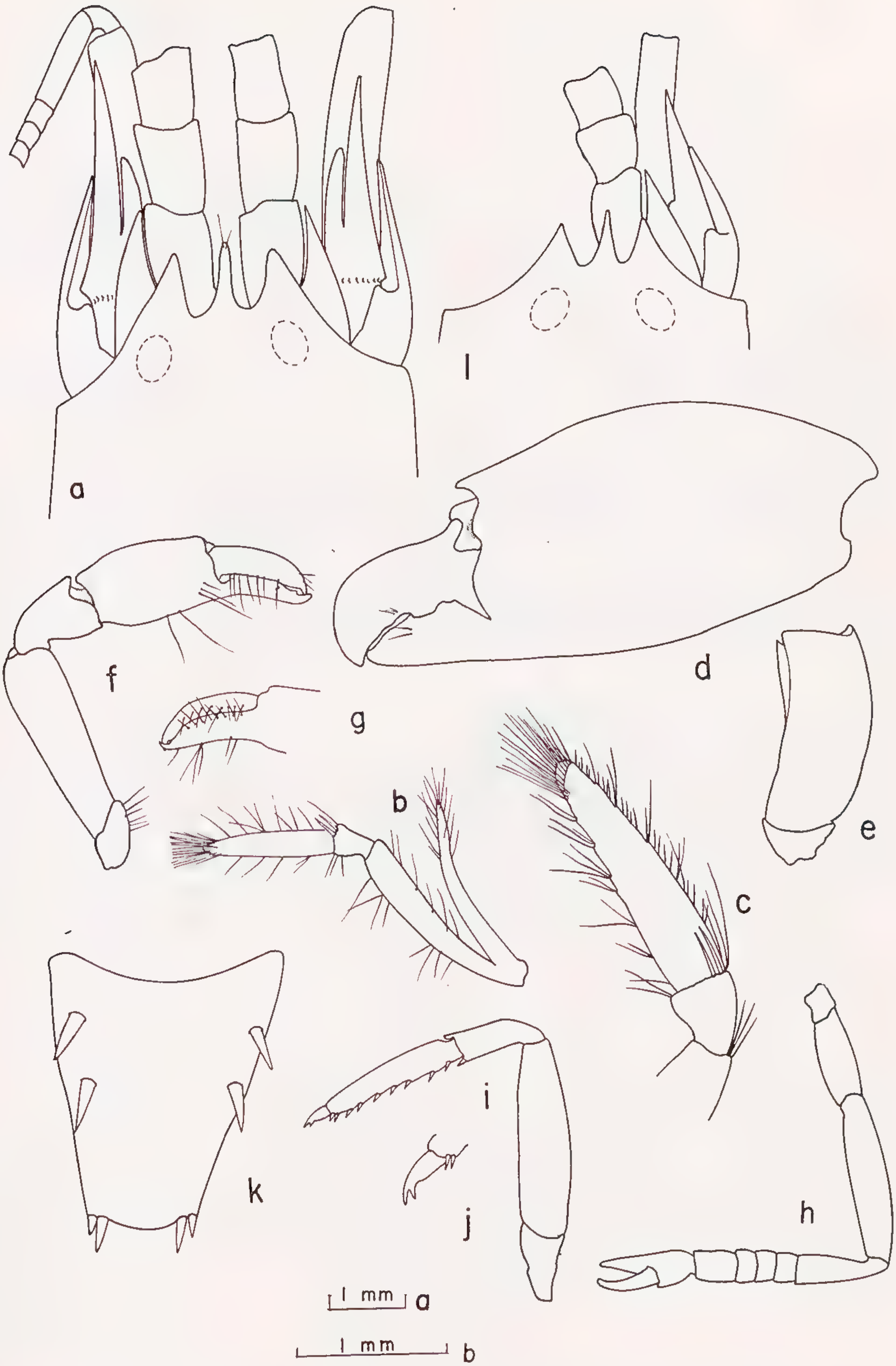
Large chela 2.4 times as long as broad; superior margin terminating in an obtuse tooth above dactylus. Merus 2.6 times as long as broad, superior and inferointernal margin each terminating in small acute tooth. Small chela 2.4 times as long as wide with fingers and palm almost equal in length. Dactylus broadened laterally, opposing surface slightly excavate and terminating in a slender obtuse tooth that crosses a similar tooth on pollex upon closure. Margin of outer face of dactylus armed with 7–9 regularly placed setae; inner face similarly armed with setae which cross in a regular fashion corresponding setae on margin of pollex. Carpus cup-shaped, varying from 0.27–0.33 the length of the chela. Merus 3.2 times as long as broad at the distal end, unarmed.

Carpal articles of second leg with ratio 10:2:2:2:4, sum of four distal articles 1.1–1.3 times length of first.

Merus of third leg inermous, 3.7 times as long as broad. Carpus 0.4 as long as merus, superodistal margin projected as an obtuse tooth, inferodistal margin bearing spine; propodus 0.7 as long as merus bearing seven spines on inferior margin and two distally. Dactylus biunguiculate, two ungui equal in length, inferior unguis slightly thicker at base.

OPPOSITE

Fig. 10.—*Synalpheus theano* De Man. 12 mm male from UQ 22: a, anterior region, dorsal view; b, c, third maxilliped and detail of ultimate article; d, e, large chela and merus; f, small cheliped, outer face; g, distal region of small chela, inner face; h, second leg; i, j, third leg and enlarged dactylus; k, telson. 18 mm female from BAU 25: l, anterior region showing lack of squame. b, e, h, i, l, scale a; a, c, f, g, j, k, scale b.



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Telson 2.2 times as long as posterior margin is wide. Posterolateral margins forming right angles; posterior margin slightly convex, spines on dorsal surface prominent and anterior to midline. Outer uropod with transverse articulation.

Discussion: For the separation between this species and *S. n. neptunus* see *Discussion* under that species (p. 318).

The specimen shown in fig. 10m is without a vestige of the squamous portion of the scaphocerite. As it compared well otherwise to the characteristics of this species, and as it was collected from a sponge (BAU 25) with other normal members of the species, it was regarded as a variation. A similar difference, however, was found in the related *S. neptunus germanus*, and there considered as one of the criteria for the erection of a new subspecies (p. 321).

Biological notes: Some of the specimens were collected from dead corals. The specimen figured was collected by A. J. Bruce from a yellow sponge *Psammoaplysilla purpurea* (Carter). De Man's specimen was collected by a dredge at 32 metres. Specimens range in size from 10–22 mm.

Australian distribution: In Western Australia specimens were collected near Perth; in northern Australia, from Darwin and Thursday Island; and in eastern Australia, from Whitsunday Group to Port Jackson, N.S.W.

General distribution: Indonesia and Singapore (it may be that Johnson (1962: 50) in his report of the species from Singapore confused *S. theano* with *S. neptunus* as we did (1966b) in our Thai study).

Synalpheus neptunus neptunus (Dana) [Subspecies designated]

Fig. 11

Alpheus neptunus Dana, 1852, U.S. Explor. Exped. 13: 553, pl. 35, fig. 5.

Synalpheus neptunus Coutière, 1909, Proc, U.S. natn. Mus. 36 (1659): 87, fig. 53. Banner & Banner, 1972, Crustaceana 23 (1): 24 [Neotype established and full synonymy given].

Additional Australian Records: [records questionable, see discussion below]

Bate, 1888, Challenger Rept. 24: 563, pl. 10, fig. 2 (as *Alpheus neptunus*). Arafura Sea.

Coutière, 1900, Bull. Mus. Hist nat., Paris 6 (8): 411. Torres Strait.

Specimens examined: 17 specimens from AM E 4494; 6, AM P 1695; 1, BAU 25; 23, BAU 28; 7, BAU 33; 1, BAU 43; 1, CS 25–28; 1, QM W 1053; 8, WM 34–65; 4, WM 183–65; 3, WM 189–65; 1, WM 243–65; 5, WM 274–65; 6, WM 289–65; 5, WM 10591/92.

Diagnosis: Rostrum with rounded tip reaching well past middle of visible part of first antennular article. Orbital teeth broader than rostrum at base and often slightly shorter. Rostral base with orbitorostral process.

First two antennular articles subequal, third a little shorter than second; second article a little longer than broad. Stylocerite varying from three-fourths length of first antennular article to a little past end. Lateral spine of scaphocerite varying from end of second antennular article to three-fourths length of third article; squamous portion variable, at times reaching to end of second antennular article, and at times vestigial. Carpocerite longer than antennular peduncles, approximately five times as long as wide. Lateral spine of basicerite reaching from end of first antennular article to three-fourths length of second; superior angle rounded, occasionally slightly projecting.

Distal article of third maxilliped 4.5 times as long as broad, bearing on its apex a circlet of 6–7 short heavy spines.

Large chela 2.5 times as long as wide, with fingers occupying distal 0.3. Palm terminating above dactylar articulation in rounded prominence. Merus 3.5 times as long as broad with end of superior margin rounded and with only a blunt prominence on distal end of both inferior margins. Small chela 2.4 times as long as wide with fingers and palm almost equal. Fingers broadened laterally, opposing surfaces excavate, both without auxiliary teeth. Margin of outer face of dactylus armed with a row of 7–9 regularly placed setae; margins on inner face armed with setae which cross in a regular fashion, similar setae on pollex. Both dactyl and pollex terminate in a single tooth. Carpus cup-shaped, varying from 0.20 to 0.50 the length of chela.

Second leg with first carpal articles slightly shorter than sum of four following; length of chela may almost equal length of sum of last four articles. Ratio of carpal articles of second legs: 10:2:2:2:5.

Merus of third leg three times as long as broad, inermis. Carpus 0.4 as long as merus, inferodistal margin armed with a solitary spinule, superodistal margin extended into rounded tooth. Propodus 0.7 as long as merus, inferior margin armed with 6–9 spinules, none distally. Dactylus biunguiculate, 2 ungui often equal in length, but inferior unguis slightly thicker at base.

Telson 2.3 times as long as posterior margin is broad; anterior margin twice as broad as posterior; posterolateral margins forming right angles; posterior margin slightly convex. Dorsal spines prominent; length of anterior dorsal pair one-third, of medial pair of posterior spines one-quarter, breadth of telson tip. Outer uropod with distal articulation in mature forms.

Discussion: In 1972 we established a neotype for this species with a specimen from the Sulu Sea, the type location, and contrasted the species to the closely related *S. theano* De Man. We were able to show that both species exhibited considerable variation in characteristics previously considered to be of value in their separation, especially in their growth patterns. However there was one reliable characteristic: In *S. neptunus* the tip of the third maxilliped bears a circlet of short strong spines (fig. 11h) while in *S. theano* the tip bears a tuft of longer, flexible setae (fig. 10c).

The largest specimens in the Australian collections were those from Exmouth Gulf which reached 26 mm in length; other specimens ranged from 7–18 mm. We have figured the rostral front, small chela and second legs of one specimen from Exmouth Gulf (fig. 11k, 1, m) as these parts were more slender than those of specimens of smaller size. We tentatively suggest that this variation is a further extension of the variation in proportion with size.

Biological notes: In the examination of the collections from Australia and the Philippines we observed a rather perplexing correlation that we had not previously noted. In this species there appears to be two different size ranges which are correlated with habitat, with an exception from the Exmouth Gulf, W.A. In those specimens which in our field notes were recorded as coming from corals or where the specific ecological niches were not noted ("dredged from 10 fathoms"), the size ranged from 18–26 mm and they contained the usual number of ovigerous females. Secondary sexual characteristics were well developed, with the females showing large rounded pleura on the abdomen and large, soft pleopods; the second pleopods of the females carried a well-developd *appendix interna* arising at slightly less than two-thirds the length of the endopod (fig. 11i). In contrast the pleura of the males were smaller, the first with a definite projected posterior tooth, the remaining pleura with the posterior margins angular. In the males of size comparable to the ovigerous females the second pleopods were shorter and apparently stronger: while the pleopods carried only the *appendix interna* as is normal for *Synalpheus*, it was shorter and originated from slightly beyond the end of the basal third of the endopod (fig. 11j). None of these apparently free-living forms was less than 8 mm long.

In contrast, large numbers in the collection were noted as coming from the cavities of sponges; within the spongocoels they occurred in great numbers (in our personal collections we removed up to fifty specimens on one sponge, but we could have collected more from larger sponges). All of these specimens were small, not reaching over 8 mm in length. None were ovigerous, and upon examination all showed a male form of abdominal pleura. In most specimens the endoped of the second pleopod had no endite; in a few of the largest there was a small

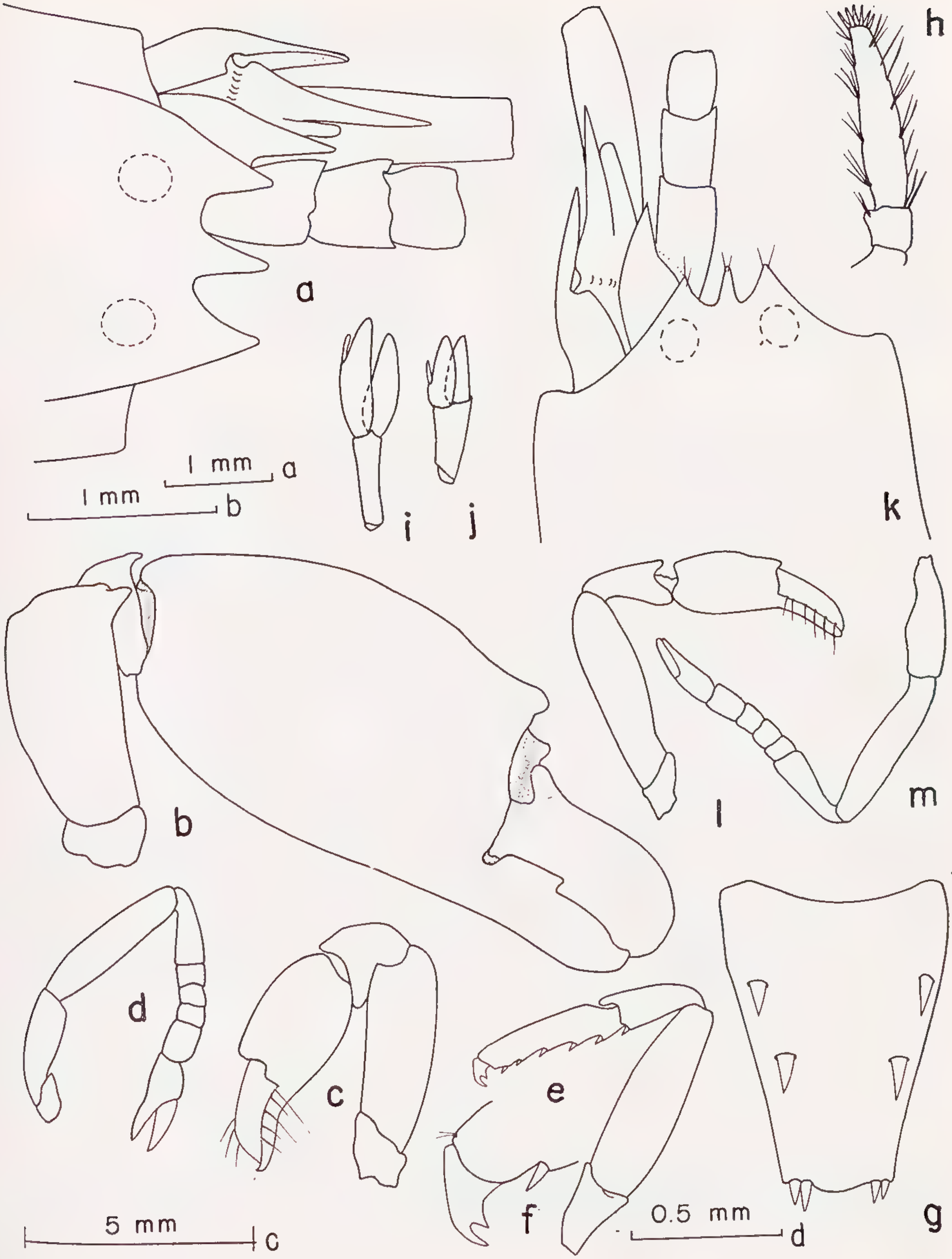


Fig. 11.—*Synalpheus neptunus neptunus* (Dana).—10 mm male from BAU 28: a, anterior region dorsal view; b, large cheliped, inner face; c, small cheliped, outer face; d, second leg; e, f, third leg and enlargement of dactylus; g, telson; h, third maxilliped. 27 mm female from WM 183-65: i, second pleopod. 28 mm male from WM 83-65: j, second pleopod. 30 mm female from WM 34-65: k, anterior region, dorsal view; l, small cheliped; m, second leg. b, c, d, e, h, scale a; a, g, h, scale b; i, j, k, l, m, scale c; f, scale d.

appendix interna in the "male position". Finally, in the smaller of the specimens the outer uropod was without the normal transverse articulation; in the larger the articulation was present but not well formed. It is known that immature synalpheids of both sexes may have abdominal pleura more like adult males (Coutière, 1909: 18). To our knowledge there have been no observations of the male-like *appendix interna* nor of the lack of transverse articulation in immature forms. Other morphological characteristics lie well within the range of variation that we have already reported upon.

The exception lies in two collections from Exmouth Gulf (CS 25–28, WM 60–65). The specimens in both of these were reported as coming from sponges gathered in trawls and both contained sexually mature specimens ranging from 10–25 mm in length (these are not the large specimens mentioned under *Discussion*).

We know of only one other case (Coutière 1909: 17) where there has been reported among the alpheids such difference in habitat with sex and sexual maturity. We suggest two possible interpretations for the observations: First, that the young of *S. n. neptunus* may settle either in the dead coral (or other similar habitats) where it will grow to maturity, or may settle in various sponges where some pheromone-like chemical given off by some species of sponges will inhibit growth and sexual maturity of the individual. This explanation does not account for the lack of the smaller individuals in the "open" habitat. Second, that the species actually uses some species of sponges as a "nursery", probably infesting it in a post-larval stage and staying within the protection of the spongocoel until it reaches the length of about 8 mm when it moves into the "open" habitat. What would cause an individual to leave the spongocoel at a particular stage of development we do not know, but we suggest it may be a change in food habits or too much spatial restriction by the narrow passages of the sponge. In the case of the two Exmouth Gulf collections these food or spatial restrictions had not applied in that particular sponge and the alpheid could reach maturity. While it will take further field observation supplemented with laboratory studies to confirm these conclusions (which are impossible in Hawaii as the species does not occur in the Central Pacific), we believe that the second hypothesis seems the more logical from the data available to us.

The Australian specimens were taken mostly from coral heads collected in shallow water; however, those from Cockburn Sound were taken from sponges dredged from 11 fathoms.

Australian distribution: Specimens from Western Australia came from Perth to Exmouth Gulf; in northern Australia from Thursday Is., in eastern Australia from Port Douglas to Port Jackson.

General distribution: Red Sea; Indian Ocean; Indonesia; China, Japan and Sulu Sea. We have not found it in the islands of the Central Pacific. There is so much confusion about the identity of *S. n. neptunus* that most older locality records cannot be relied upon.

Synalpheus neptunus germanus subsp. nov.

Fig. 12

Holotype: 11 mm specimen collected from sponge by G. Glauert, 14/8/22, at Cottesloe, W.A. (WM 9991), apparently an immature male.

Paratypes: 16 specimens, 10–15 mm from same location as the holotype; eighteen specimens, 10–15 mm from Rottnest, W.A. (WM 32–65); nine specimens 7–14 mm from Cottesloe, W.A. (AM P 12426). [All paratypes apparently immature males.]

Description: Rostrum almost reaching to end of first antennular article. Orbital teeth with tips rounded, almost as long as rostrum, but much broader at base, almost forming an equilateral triangle. Rostral base with orbitorostral process.

Antennular peduncle stout, articles subequal, second antennular article a little broader than long. Stylocerite a little longer than first article. Scaphocerite with lateral spine reaching almost to end of third antennular article; squamous portion absent. Carpocerite reaching well past antennular peduncle, 4.5 times as long as wide in lateral view. Basicerite with superior margin slightly projected but rounded; inferior spine a little longer than stylocerite.

Distal end of third maxilliped armed with a circlet of spinules.

Large cheliped 2.6 times as long as broad, distal end of superior margin proximal to palm produced into an obtuse tooth, tilted slightly upward. Finger 0.3 as long as entire chela. Merus two times as long as broad, distal ends of both inferior margins armed with slightly produced, obtuse teeth; superior margin not produced.

Small chela 3 times as long as broad, palm a little shorter than fingers; fingers laterally expanded and excavate; distal part of pollex on inner face bearing four patches of setae which curve upwards and forwards so that when viewed from the inner face they appear as a fan of setae (fig. 12f). Outer face of dactylus with two rows of setae placed longitudinally; superior row located below crest with evenly spaced follicles, each bearing one or two setae; inferior row located along oppositional margin, similar to that of *S. n. neptunus*. A few setae on the palm close to base of pollex. Carpus one-quarter length of chela, bearing a few setae on inferoexternal margin. Merus 0.8 length of chela and 2.5 times as long as broad.

Carpal articles of the second leg with a ratio: 10:2:2:2:6. Second to fourth articles broader than long; chela twice length of distal article.

Merus of third leg almost 3.5 times as long as broad. Carpus 0.4 as long as merus, distosuperior margin projecting as subacute tooth, inferodistal margin bearing movable spine. Propodus 0.7 as long as merus, bearing on inferior margin five spinules and two distally. Dactylus biunguiculate, ungui almost equal in length, apex between forming a "U".

Telson 2.7 times as long as wide at the posterior margin, anterior margin 2.5 times breadth of posterior; posterolateral margins forming right angles; telsal tip almost straight. Length of anterior pair of dorsal spines over half, of medial pair of posterior spines less than half, breadth of telson tip. Outer uropod without distal articulation.

Discussion: Somewhat similar to the specimens of the nominate subspecies which were also collected from sponges, all forty-four of these specimens appeared to be juvenile, none carried ova. All had the angular corners of the abdominal pleura and all lacked the transverse articulation of the outer uropod. However, possibly because of their slightly larger size, all had an *appendix interna* in the basal third of the endopod of the second pleopod. As in *S. neptunus neptunus*, we have interpreted these characteristics as being those of sexually immature juveniles. Evidently the same factors influence the form of the two subspecies.

This collection shows far less variation than does that of the nominate subspecies and the related *S. theano;* the spines on the end of the third maxilliped shows it definitely to be related to *S. n. neptunus*. The differences between this subspecies and *S. n. neptunus* are small but constant in these collections: 1. In this subspecies the squame is usually absent, and at most a mere vestige, while in the nominate subspecies it usually is of moderate development and only rarely reduced to a vestige. (We differentiate between the vestigial form and the complete absence of the squame by the presence or absence of a slit between the lobe and the lateral tooth). 2. The dactylus of the small chela bears an additional row of setae on the outer face, superior to the marginal row. 3. The tip of the telson is narrower, and the spines are longer, the anterior margin is 2.5 times the breadth of the tip instead of 2.0 times as in *S. n. neptunus*. 4. The tip of the telson is less arcuate. We regard the second point as the most reliable.

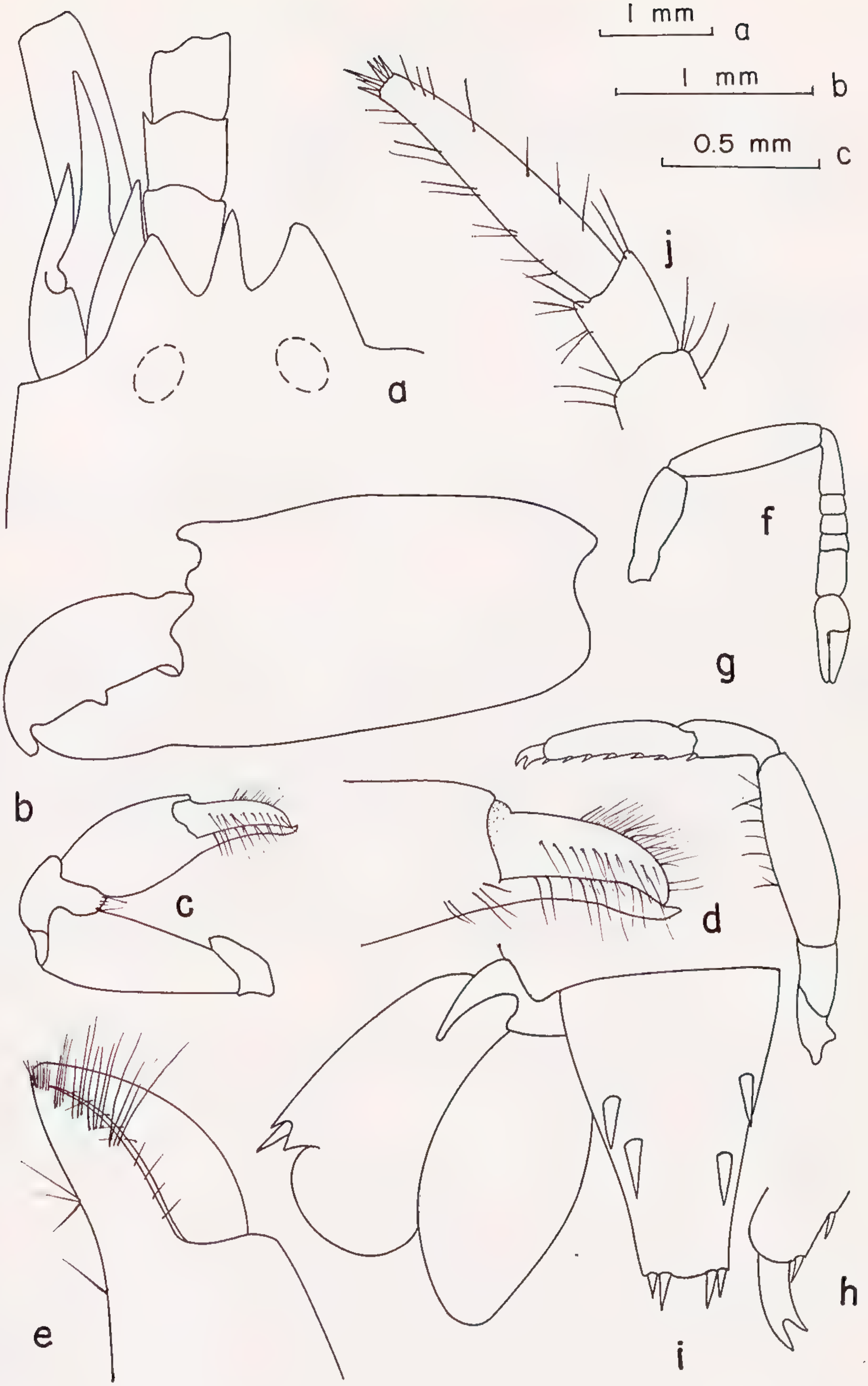
In the consideration of the division of this species into two subspecies it should be noted that all specimens came from the immediate vicinity of Fremantle, W.A., while *S. n. neptunus* is widespread in the Western Pacific and Indian Ocean, as well as in the Fremantle area.

We suggest that this form is a variant of *S. neptunus* which is adapted to live as a juvenile in a particular sponge found in the Fremantle area of Western Australia. We are quite sure that many of the characteristics, like the lack of an articulation in the uropod, will change with maturity, similar to the growth changes we have reported for the nominate subspecies (1972:24, and above). However, we believe these growth changes will not obliterate all the criteria we have established to separate the two subspecies.

The subspecific name is from the Latin word meaning "of the same parent" and was selected to indicate the close relationship of the two subspecies. The holotype will be deposited in the Western Australian Museum.

OPPOSITE

Fig. 12.—*Synalpheus neptunus germanus* subsp. nov. Holotype: a, anterior region, dorsal view; b, large chela, inner face; c, d, small cheliped, outer face and enlargement of distal region; e, enlargement of distal end of small chela, inner face; f, second leg; g, h, third leg and enlargement of dactyl; i, telson. 17 mm male from WM 10591/92: j, distal region of third maxilliped. b, e, f, g, scale a; a, d, e, i, scale b; j, h, scale c.


1 mm a
1 mm b
0.5 mm c
a
b
c
d
e
f
g
h
i
j

Synalpheus demani Borradaile

Fig. 13

Synalpheus demani Borradaile, 1900, Willey's Zool. Res. 4: 416. De Man, 1911, Siboga Exped. 39a[1] (2): 257, fig. 42. Banner & Banner 1968, Micronesica 4 (2): 274. Miya, 1972, Publ. Amakusa Mar. Biol. Lab. 3 (1): 60, pl. 11.

Alpheus triunguiculatus De Man, 1888a, Archiv. Naturgesch. 53: 504, pl. 22, fig. 1 (*nec* Paulson).

Synalpheus spiniger Bate, 1888. Challenger Rept. 24: 560, pl. 100, fig. 3 (*nec* Stimpson).

Synalpheus brockii Nobili, 1901, Ann. del Mus. Zool. Napoli 1 (3): 2.

Specimens examined: Four specimens from AM 177.

Diagnosis: Rostrum slender, over twice as long as broad, reaching to end of first antennular article. Orbital teeth shorter and broader at base than rostrum, but strongly acute. Pterygostomial angle more projecting than usual for the genus. Rostral base with orbitorostral process.

Visible part of first antennular article scarcely 1.5 times as long as second article; second article about 1.5 times as long as broad and 1.5 times as long as third article. Stylocerite acute, reaching to near middle of second antennular article. Squamous portion of scaphocerite reaching to middle of third antennular article, lateral spine reaching to end of same article. Carpocerite, viewed laterally, 4.5 times as long as broad, reaching past end of third antennular article. Lateral margins of distal half of carpocerite beset with setae. Inferior spine of basicerite almost as long as stylocerite and bearing setae on distolateral margin; superior spine acute, a little longer than orbital spines. Superior margin of basicerite bearing third short subacute tooth medial and proximal to superior tooth.

Large chelae missing in all available specimens. (De Man, 1888a, pl. 22, fig. 1 shows the large chela to be three times as long as broad, margin superior to dactylar articulation unarmed and rounded; distal angles of merus not projecting.)

Small chela 3.5 times as long as broad, fingers 0.7 as long as palm. Carpus about one-sixth as long as chela. Merus 2.5 times as long as broad, inermis, but bearing along superior margin groups of short setae and individually placed fine setae along inferior margin.

Carpal articles of second leg with ratio 10:2:2:2:3; second and third articles as broad as long.

Third leg stout. Ischium and merus unarmed; merus 3 times as long as broad. Carpus short, 0.4 as long as merus and heavy, 0.6 as broad as long; inferodistal margin rounded and bearing a few setae; superodistal margin extended as a heavy tooth. Propodus as long as merus, curved, proximal portions unarmed but bearing distally three small spinules and several dense patches of setae. Dactylus heavy, almost one-third as long as prodous, triunguiculate. Middle unguis two or three times length of superior unguis; inferior unguis about 1.5 length of superior; inferior unguis usually slightly broader at base than at middle.

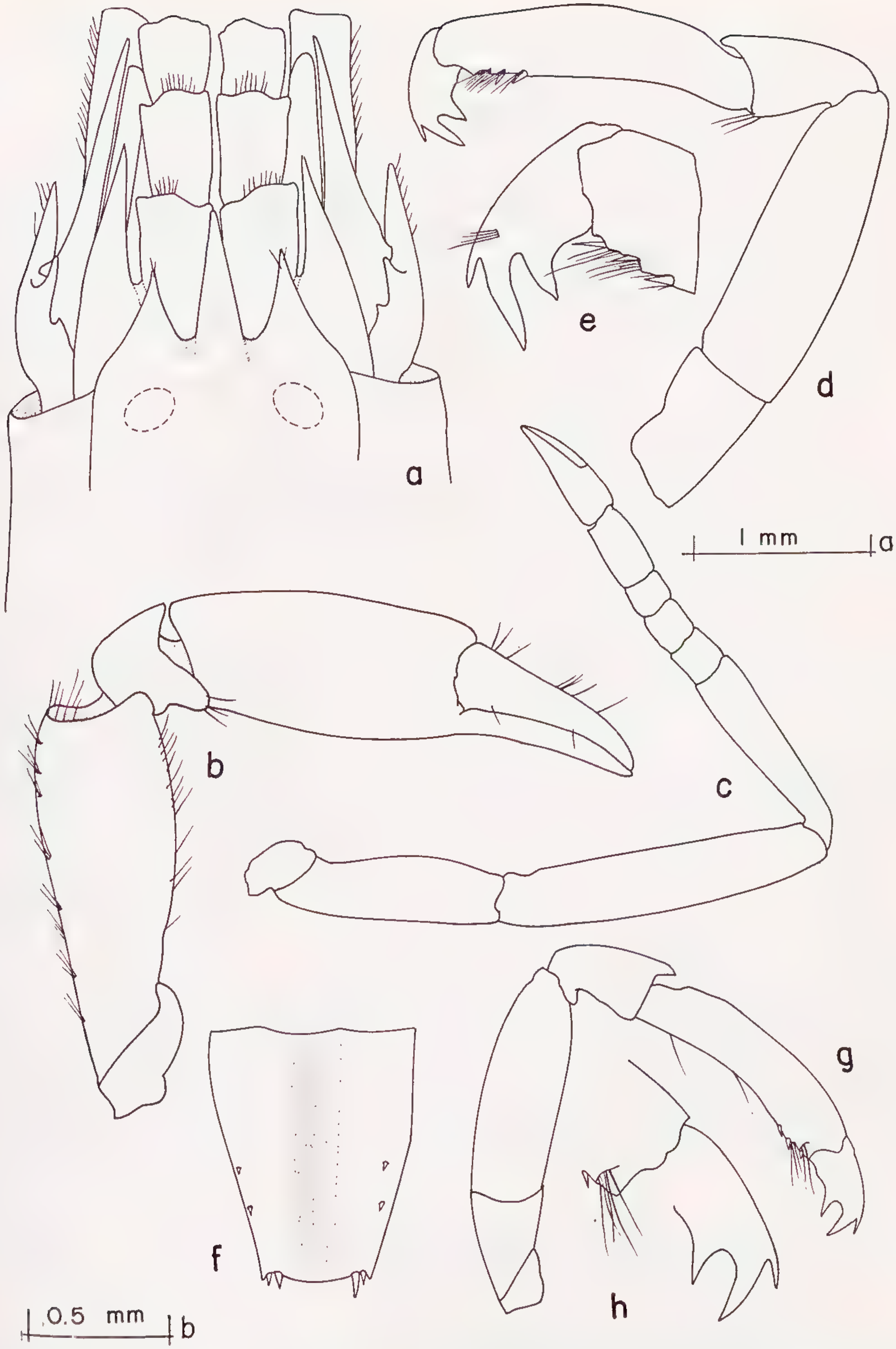


Fig. 13.—*Synalpheus demani* Borradaile. 20 mm male AM 177: a, anterior region of carapace, dorsal view; b, small cheliped; c, second leg; d, e, third leg and enlarged dactylus; f, telson. Bate's specimen from the Challenger Report: g, h, third leg and enlargement of dactylus. All drawings except e and h, scale a; e and h, scale b.

Telson 2.1 times as long as broad at posterior margin, posterolateral margin slightly produced and acute. Dorsal surface slightly concave medially, with spinules small and located posterior to middle and near lateral margins, or absent. Outer uropod with transverse articulation.

Discussion: Our four specimens appear to be two pairs. Both males are 20 mm long while the females which are ovigerous, are 30 mm long. The gastric region of the carapace of the female also has a "humped-up" appearance similar to *S. carinatus* (De Man) while the carapace of the male is flattened. The spines on the upper surface of the telson are variable: the male drawn had four small spines, one female carried one spine and in the other two specimens all spines were lacking. Miya (1972) remarks on two smaller males in his collection that have only four articles in the carpus of the second legs. He stated that these also had a rudimentary *appendix interna* on the second pleopods, a process absent in larger males.

This species is most closely related to *S. triunguiculatus* Paulson, but is separated by at least three characteristics: 1. In *S. triunguiculatus* there is a hooked tubercle at the distal end of the palm of the large chela while *S. demani* has none; 2. the inferior margin of the propodus of the third leg in *S. triunguiculatus* carries eight strong spinules while in *S. demani* there are only three spinules near the distal end; 3. the spines on the dorsal surface of the telson of *S. triunguiculatus* are strong while in *S. demani* they are small and weak or entirely absent.

We were able to examine Spence Bate's specimen that he named *S. spiniger* (Stimpson) from the Challenger Expedition at the British Museum of Natural History and found it to be *S. demani*. *S. spiniger* is described as having only two ungui on the dactyli of the third legs " . . . *unguiculus secundus dactyli minutus ventralis, retrorsum curvatus*" (Stimpson 1861: 31). Bate apparently failed to note the third unguis on his specimen. We have figured the third leg and dactylus of Bate's specimen (fig. 13g, h). The groove he depicted on the large chela (pl. C, fig. 3k) is not a true groove but an artifact.

Some of the synonymy has arisen as De Man applied the name *S. triunguiculatus* to a new species, apparently unaware that Paulson had previously published the name for a different species. Both Borradaile and Nobili corrected this error, but Borradaile's correction has priority.

Biological notes: While these four specimens were collected by dredging without notes on a possible symbiotic association, the species is known often to be in association with crinoids (Banner & Banner, 1968: 274). Miya stated that all of his specimens from Japanese waters were found living in association with *Comanthina schlegeli* (Carpenter). Dr R. U. Gooding also has sent us specimens from off Samarai, Papua, which were collected, together with other comatulid-associated synalpheids, from a dredge haul consisting of almost nothing but crinoids.

Both Miya and ourselves have given colour notes; these differ, and indicate that like other symbionts, the species may change its colour to match that of the host (*see* Appendix, p. 156).

Australian distribution: Our specimens were dredged between Shark Bay and Cape Farquar, Western Australia.

General distributions: Red Sea (as *S. brockii* Nobili); Indonesia: Philippines (Visayan Sea as *S. spiniger* by Bate); Japan; Loyalty Is.; Marshall Is.

Synalpheus nilandensis Coutière

Fig. 14

Synalpheus nilandensis Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 871, fig. 4. De Man, 1911, Siboga Exped. 39a[1] (2): 246, fig. 38.

Synalpheus nilandensis var. *oxyceros* Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 871, fig. 5. De Man, 1911, Siboga Exped. 39a[1] (2): 246, fig. 38c, d.

Synalpheus nilandensis var. *bandaensis* De Man, 1911, Siboga Exped. 39a[1] (2): 249, fig. 38a, b.

Specimens examined: 1 specimen from AC S4; 3, WM 192–65; 1, WM 230–65.

Diagnosis of Australian form: Rostrum narrow, reaching to middle of first antennular article. Orbital teeth as long as rostrum, but broader at base, rostrum and orbital teeth tilted upwards at tips. Rostral base with orbitorostral process.

Visible part of first antennular article twice as long as second article; second article longer than broad, third article shorter than second. Stylocerite reaching to middle of second antennular article. Scaphocerite with narrow squame reaching to first quarter of third antennular article, lateral spine reaching to tip of carpocerite. Carpocerite viewed from below 4.4 times as long as broad, reaching length of third antennular article past that article. Lower spine of basicerite reaching to near end of first antennular article, upper spine prominent, acute.

Large chela three times as long as broad, fingers 0.3 of total length. Palm bearing acute tooth above dactylar articulation. Merus 2.8 times as long as broad, superodistal margin terminating in acute tooth, lower distal margins rounded. Small chela 3.5 times as long as broad, fingers 0.4 as long as palm. Merus 2.6 times as long as broad; superodistal margin with acute tooth.

Carpal articles of second leg with ratio: 10.1:1:1:3.

Merus of third leg 3.5 times as long as broad, inferior margin armed distally with about four strong spines. Carpus 0.4 as long as merus, superodistal margin projecting but rounded, inferodistal margin bearing strong spine. Propodus slender, almost as long as merus, bearing on its inferior margin about 12 spines and a pair distally. Dactylus triunguiculate, 0.2 as long as prodous, middle unguis largest, almost following curvature of dactyl; superior unguis three-fourths as long and much thinner than middle unguis; inferior slender, acute, slightly shorter than superior; notch between middle and superior ungui triangular and acute, between middle and inferior broadly rounded.

Telson 2.7 times as long as broad at posterior margin. Posterolateral angles extending in short, acute teeth, but teeth never shorter than outer pair of posterior spines. Outer uropod with transverse articulation.

Discussion: We have found it impossible to resolve the *S. nilandensis* complex on the basis of the present collections and past descriptions. Previously described are the parent species and two additional varieties from the Maldives by Coutière and by De Man from the Siboga Expedition. These descriptions are

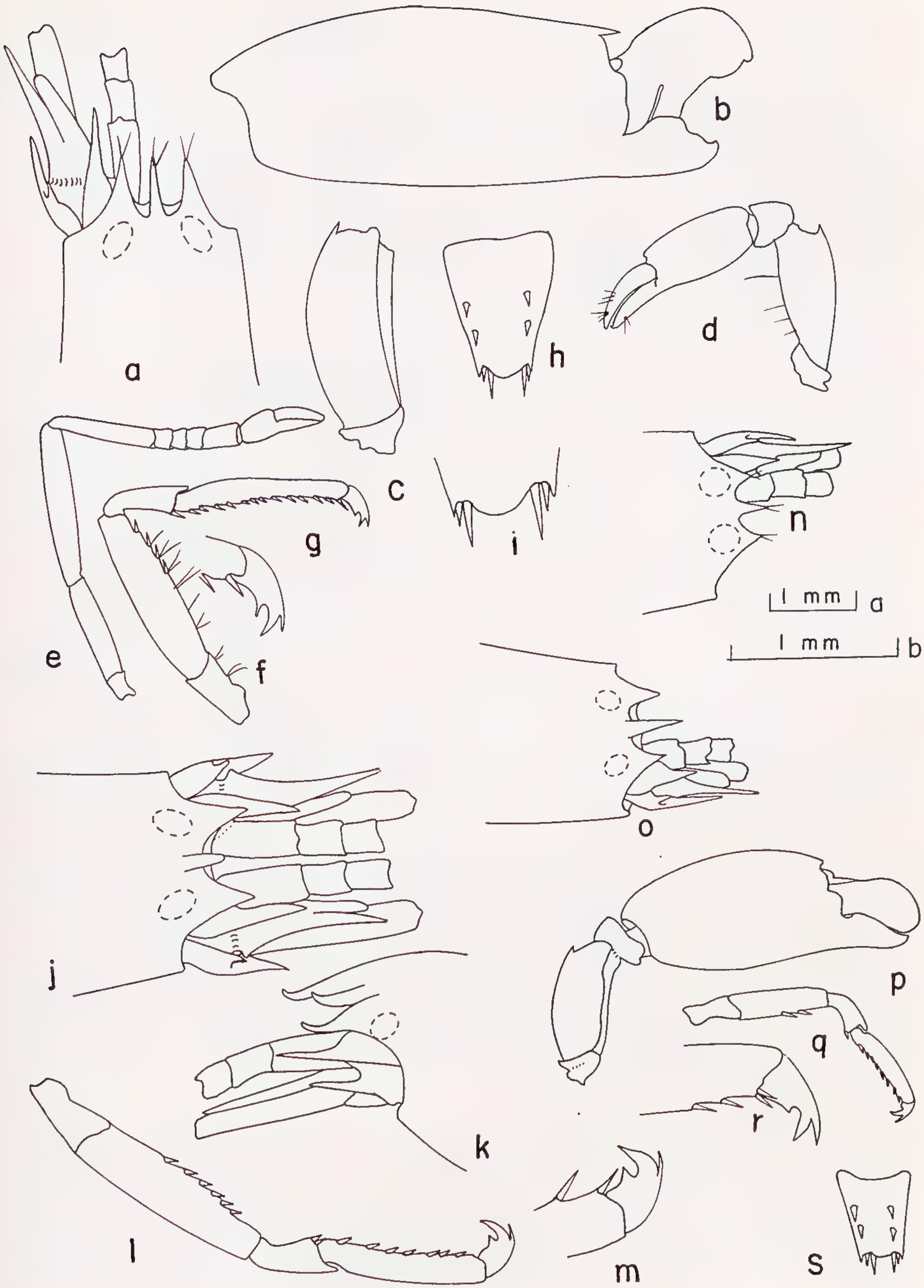
not complete and do not completely agree as De Man's interpretations differ from those of Coutière. Coutière's work was based on six specimens; De Man had a total of seven specimens. Coutière noted that three of his specimens came from gorgonians; none of De Man's were noted to be symbionts. We have before us the listed five specimens from Western Australia; twelve specimens from the Andaman Sea, collected by the International Indian Ocean Expedition; eighteen specimens from near Hong Kong, two from near Borneo loaned by the Fisheries Research Station of Hong Kong; and also two specimens from the Red Sea collected by the University of Israel Red Sea Expedition. We have also re-examined all of De Man's Siboga specimens at the courtesy of the Zoölogisch Museum, Amsterdam. As these specimens fall into five imperfectly separated groups, we are describing both the previously named varieties and our new varieties as "forms", outside the rules of nomenclature (Article I 10 (b) and 45 (e) (i) of the International Code of Zoological Nomenclature, 1961). This device will permit future workers reviewing the complex to raise or eliminate these designations on the basis of parameters of variation found within populations.

S. nilandensis forma *nilandensis* (Coutière, 1905a: 871). This form has a slender rostrum, equal in length to the orbital teeth, reaching about two-thirds the length of the first antennular article. The first antennular article is twice as long as broad; the stylocerite reaches well past the end of the first article. The lateral spine of the scaphocerite reaches to end of carpocerite which is the length of the third antennular article past that article; the squame reaches to the end of the antennular peduncle. The lateral spine of the basicerite reaches to the level of the first antennular article, but is shorter than the stylocerite. The dactylus of the third leg is 1.5 times as long as broad, the superior unguis slender and reduced, the middle unguis heavy and turning at right angles to the axis of the dactyl. The inferior unguis is shortest and forms almost a semicircle where it meets the middle unguis. This combination of characteristics is not found in our collections. Coutière remarked that three of his specimens came from gorgonians.

S. nilandensis forma *oxyceros* (Coutière, 1905a: 871). This form was erected by Coutière in a short paragraph and illustrated by only two drawings. It was separated from the parent form by: 1. the stylocerite reaching the middle of the second antennular article; 2. the inferior tooth of the basicerite reaching the end of the same article; 3. the lateral tooth of the scaphocerite reaching 1.5 times the length of the third antennular article past the end of the carpocerite; 4. the dactylus of the third leg being 2.2 times as long as broad and the superior unguis being heavier and longer than in the nominate form. We do not have this form in our collections.

OPPOSITE

Fig. 14.—*Synalpheus nilandensis* Coutière. *Forma bandaensis.* 14 mm male from WM 192-65: a, anterior region, dorsal view; b, c, large chela and merus, inner face; d, small cheliped; e, second leg; f, g, third leg and enlargement of dactyl; h, i, telson and enlargement of posterior region. *Forma alpha* 15 mm male from *IIOE* Sta. 22A (Andaman Sea): j, k, anterior region, dorsal and lateral view; l, m, third leg and enlargement of dactyl. *Forma beta* 10 mm female from Aabak Is. (Southern Red Sea): n, anterior region, dorsal view. 12 mm ovigerous female from Siboga Sta. 282: o, anterior region, dorsal view; p. large cheliped; q, r, third leg and enlargement of dactylus; s, telson. a, b, c, d, e, f, h, j, k, l, n, o, p, q, s, scale a; g, i, m, r, scale b.



a
b
c
d
e
f
g
h
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j
k
l
m
n
o
p
q
r
s
1 mm a
1 mm b

S. nilandensis forma *alpha*. This form is represented by one of De Man's three specimens that he attributes to the nominate form of *S. nilandensis* (1911: 247, fig. 38). It is represented in our collection by nine specimens from the Andaman Sea, two from near Borneo and four from Hong Kong (see figs 14 j, k, l, m). It is characterized by having the rostrum markedly shorter than the orbital teeth, and having the orbital teeth somewhat divergent; the three are slightly upturned on the ends and they are markedly shorter than the first antennular article. The antennular and antennal articles approach the proportions of the nominate species. The middle unguis of the third leg is at right angles to the axis of the dactylus, but is slightly more slender than one figured by Coutière. One specimen from Hong Kong and one from Borneo were reported as symbiotic with the ophuroid *Gorgonocephalus;* no other associations were commented upon in the collecting notes.

S. nilandensis forma *bandaensis* (De Man, 1911: 248, fig. 38a, b). De Man described this variety on the basis of three specimens; our five Australian specimens as well as three specimens from the Andaman Sea and fourteen specimens from near Hong Kong, we place in this form (fig. 14 a-i). In this the rostrum, orbital teeth and antennular and antennal bases are almost identical to the nominate form; it differs in the form of the dactylus of the third legs. The dactylus here is 2.5 times as long as broad, more slender than in the nominate forms; the superior unguis is half as long to as long as the middle unguis the middle unguis is slender, about twice as long as broad at the base and lies at an angle of 45° to the axis of the article; the inferior unguis usually is a small but slender and acute tooth. Neither the specimens of De Man nor those from Australia were reported in symbiotic association, but the fourteen specimens from Hong Kong came from a "hard sponge".

S. nilandensis forma *beta*. The single specimen described by De Man as *S. n. oxyceros* (*nec* Coutière) belongs to this form, as well as two specimens we have from the Red Sea. The three specimens do not conform, and perhaps should be described as three separate forms. The rostrum in the Red Sea specimens is either as long as or slightly longer than the orbital teeth, but in De Man's specimens it is one third longer than the teeth; in one of the Red Sea specimens the rostrum is markedly shorter than the first antennular article, in the other the rostrum is as long as the article and in De Man's specimen it exceeds the length of the article. However, all are similar in having short, heavy articles of the antennular peduncles, with the second article less than 1.5 times as long as broad, and the first and second articles subequal in length. There are only slight differences among the three specimens in the relative lengths of stylocerite, scaphocerite, carpocerite and basicerite. The dactylus of the third leg is like that of *S. n. bandaensis* (including the specimens De Man labelled as *S. n. oxyceros*) in which we found the upper unguis to be less strongly bent than shown in his drawing. These three specimens had no symbiotic association noted.

Thus the separations between the forms are slight and variable. If any of the forms are obligate symbionts, with each form specializing in a sponge, gorgonian or ophiuroid, they might well be considered as separate species. If, on the other hand, the species is primarily free-living with opportunistic symbiosis which might select or impose certain adaptations within the normal range of variation, the differences could be viewed as without systematic worth as they have been caused by habitat. Finally, it may be that these forms represent isolated

breeding populations that should be considered to be of subspecific worth (considering the broad and at times overlapping distribution of the forms, this is not likely). Certainly, the present collections do not indicate which of the three choices is correct.

Biological notes: These Australian specimens were collected between 19 and 73 fathoms. Other specimens reported upon were dredged from similar depths. Specimens from all locations mentioned above ranged from 10–16 mm in length.

Australian distribution: The specimens were only from Western Australia, from Houtman Abrolhos, Exmouth Gulf and Dirk Hartog Island.

General distribution: Red Sea*; Maldives and Laccadives; Andaman Sea*; Indonesia; Borneo*; Hong Kong*; Tuamotus Archipelago (Nobili, 1907:353—it is interesting to note that this one specimen was "commensale dell'ostrica perlifera" from a 25 m depth; to our knowledge this is the only record of an alpheid symbiotic with pearl oysters).

Synalpheus heroni Coutière

Synalpheus heroni Coutière, 1909, Proc. U.S. natn. Mus. 36 (1659): 42, fig. 24. De Man, 1911, Siboga Exped. 39a[1] (2): 256, fig. 41.

Nec Synalpheus heroni Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 55, fig. 16.

Specimens examined: 1 specimen from BAU 30; 3, BAU 32; 2, BAU 33; 1, WM 192–65.

Diagnosis: Rostrum reaching past middle of visible part of first antennular article. Orbital teeth the same length, but forming almost an equilateral triangle. Rostral base with orbitorostral process.

Antennular peduncle stout, antennular articles subequal, second article 1.5 times as long as broad. Stylocerite reaching to near middle of second antennular article. Lateral spine of scaphocerite reaching to end of carpocerite; squamous portion more narrow than tooth, reaching only slightly past end of second antennular article. Carpocerite varying from 3–4 times as long as broad, approaching length of third antennular article past that article. Inferior tooth of basicerite a little longer than stylocerite; superior tooth prominent, acute.

Large chela 2.4 times as long as broad, fingers occupying the distal 0.3. Superior margin of palm terminating in obtuse protusion; inferior margin slightly concave opposite dactylar articulation. Dactylus heavy with normal plunger; oppositional face distal to plunger narrow, proximally developed on outer side as a ridge with a slight longitudinal depression in middle, distally as a single sheering blade; inner face rounded; tip heavy, rounded and crossing tip of pollex. Pollex with a normal "socket" or cavity for plunger; outer face bearing strong, slightly curved ridge that meets exactly with both the longitudinal depression and the blade of dacytlus. Distal to socket, inner face with a rounded transverse depression that reaches almost to outer ridge; demarked distally by low rounded cusp; from cusp to tip, face rounded; tip acute. No structures on dacytlus meet either depression or cusp of pollex. Ridges and tip of both fingers of thick, hard, translucent chitin.

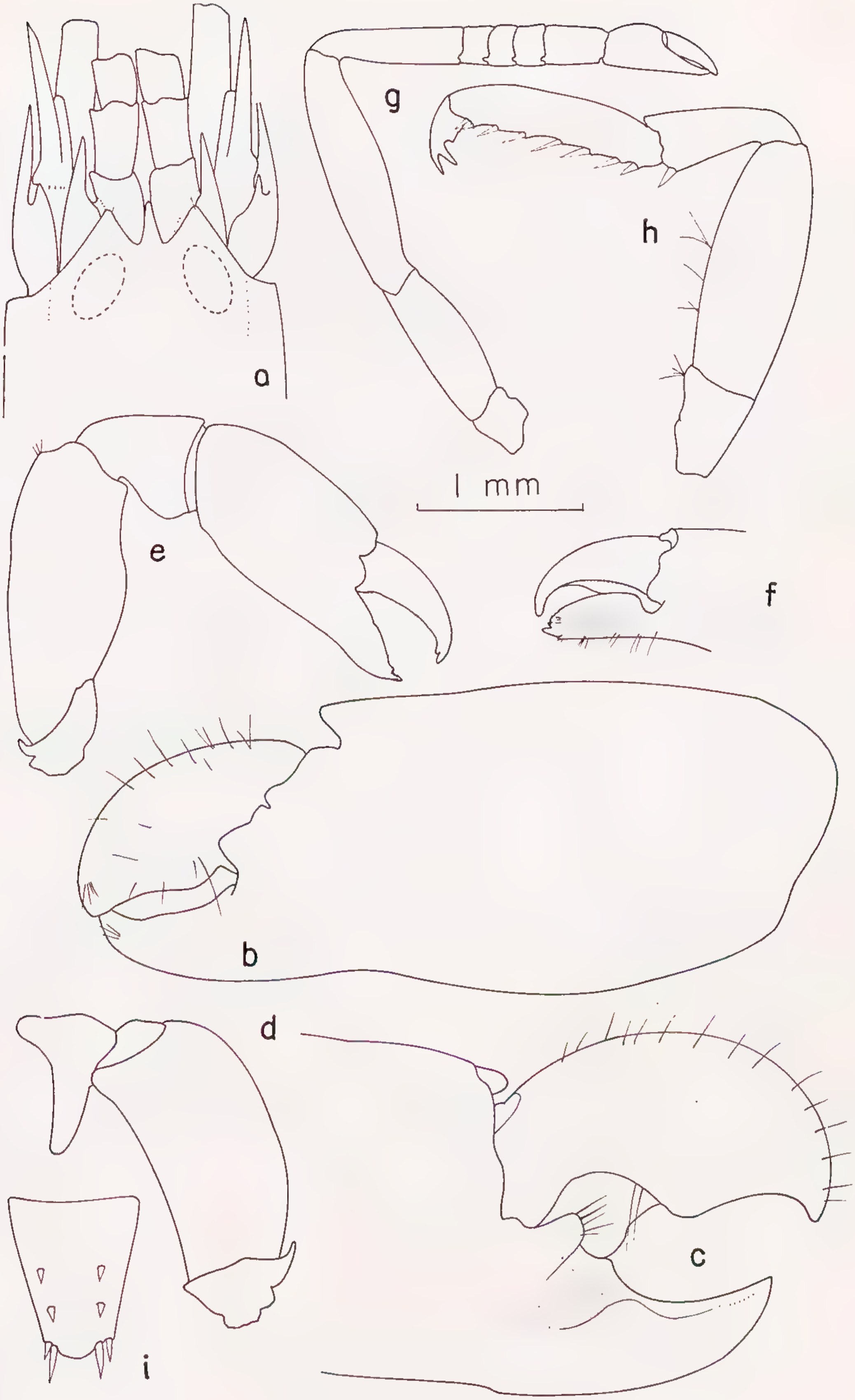
Small chela stout, 2.5 times as long as broad, fingers shorter than palm. Tooth at tip of dactylus and pollex accompanied by a small tooth medial to tip. Outer face of pollex concave. Carpus a little shorter than fingers. Merus as long and almost as broad as chela, distosuperior margin slightly projecting.

Carpal articles of the second leg with a ratio: 10:2:2:2:4.

Merus of third leg stout, inermous, 3.6 times as long as broad. Carpus 0.5 as long as merus; inferodistal margin terminating in spine; superodistal extending as obtuse tooth. Propodus a little shorter than merus, bearing on inferior margin 6 spines and a pair distally. Dactylus triunguiculate. Inferior unguis only slightly

OPPOSITE

Fig. 15.—*Synalpheus heroni* Coutière. 10 mm female from BAU 33: a, anterior region, dorsal view; b, large chela, inner face; c, large cheliped, outer face, distal region; d, merus, large chela, inner face; e, small cheliped, inner face; f, detail of distal region of small chela outer face; g, second leg; h, third leg; i, telson. All figures same scale.



a
g
h
e
1 mm
f
b
d
c
i

projecting to form right angle to proximal inferior margin of dactyl. Superior and middle ungui curved gradually, slightly divergent and equal in length, but middle unguis slightly thicker at base.

Telson 2.2 times as long as posterior margin is broad.

Discussion: This species, described by Coutière from the Red Sea, is remarkably close to *Synalpheus nobili* that Coutière described from Ecuador. We were able to examine the type of *S. heroni* as well as the type of *S. nobili* at the Smithsonian Institution. We also examined 24 specimens of *S. nobili* reported upon by Schmitt (1939: 12) from Clipperton Is. The only consistent differences between *S. nobili* and *S. heroni* are that in *S. nobili*: 1. the squame is less reduced; 2. the lateral spine of the scaphocerite is shorter than the carpocerite; 3. the large chela does not have the depression proximate to the cavity of the plunger; 4. the carpus of the small chela is shorter in relation to the chela; 5. the extra unguis of the inferior margin of the dactylus of the third thoracic leg forms an obtuse angle. These characteristics are known to be variable in other species, but as we could find no overlapping between the specimens from the Eastern Pacific and our specimens from the Great Barrier Reef, we have to consider the species separate and distinct. Certainly the Eastern Pacific Barrier would favour speciation.

We have re-examined the sole specimen from Thailand (Banner & Banner, 1966b: 55, fig. 16) that we identified as *S. heroni*. We do not believe the identification was correct. It does not have the concavity opposite the dactylar articulation of the large chela so characteristic of *S. heroni;* the squame is not reduced and the small chela bears a row of setae on the superior surface of the dactylus similar to *S. hastilicrassus* Coutière. However, unlike *S. hastilicrassus* the posterolateral margins of the telson are not spinose. We will rename the species in a future paper dealing with the Thai alpheids.

Biological notes: Our specimens were taken from dead coral heads in water up to 15 feet deep. They ranged in size from 10–14 mm long.

Australian distribution: Six of the specimens were taken from the Great Barrier Reef east of Port Douglas, Queensland, and one from near Dirk Hartog Island in Western Australia.

General distribution: Red Sea; Indonesia; Fiji; Phoenix and Line Islands: Society Archipelago.

Synalpheus fossor (Paulson)

Fig. 16

Alpheus fossor Paulson, 1875, Invest. Red Sea Crust., p. 103, pl. 13, fig. 5.

Synalpheus fossor Coutière, 1905a, Fauna and Geog. Mald and Laccad. 2 (4): 872, pl. 70, fig. 6. Tattersall, 1921, Trans. Linn. Soc. Lond. 34 (229): 374.

Synalpheus fossor var. *propinqua* De Man, 1911, Siboga Exped. 39a[1] (2): 250, fig. 39.

Synalpheus bakeri Coutière, 1908a, Bull. Soc. philomath. Paris IX, 11 (5): 199 [species described from S. Australia].

Synalpheus bakeri var. *stormi* De Man, 1911, Siboga Exped. 39a[1] (2): 253, fig. 40. Banner & Banner, 1966, Siam Soc. Mono. 3, p. 53, fig. 15.

Alpheus sp. varietas B De Man, 1897, Zool. Jb. Syst. 9:741, pl. 35, figs 62c and 62cc [= *S. bakeri stormi* acc. De Man, 1911, *loc. cit.*].

Additional Australian Records:

Coutière, 1909, Proc. U.S. natn. Mus. 36 (1659): 91 [repeat of Coutière, 1908a, *loc. cit.*].

Hale, 1941, Rep. B.A.N.Z. Antarct. Exped. B, 4 (9): 265 [as *S. bakeri stormi,* off S.W. Australia].

Specimens examined: 1 specimen from AM 63; 1, AM. 140; 20, AM E 4499; 1, AM E 4500; 2, AM P 6107; 3, BAU 25; 5, BAU 27; 2, BAU 28; 2, BAU 30; 7, BAU 40; 2, BAU 43; 9, QM W 2239; 1, WM 108–65.

Diagnosis: Rostrum slender, acute, reaching variously from middle of first antennular article to one-fourth length of second antennular article. Orbital teeth varying from 0.6 as long as rostrum to almost equal. Tip of rostrum and orbital teeth bearing a few short stiff setae and at times tilted upward. Rostral base with orbitorostral process.

Second antennular article 0.8 as long as visible part of first, third antennular article a little more than half as long as second. Stylocerite reaching almost to middle of second antennular article. Scaphocerite with narrow squame reaching variously from end of second antennular article to end of third. Carpocerite 6.0 times as long as broad, reaching from half the length to full length of third antennular article past that article. Inferior tooth of basicerite near length of stylocerite; superior tooth well developed.

Large chela cylindrical, about 2.5 times as long as broad, with fingers occupying the distal 0.3. Palm proximal to dactylus bearing one or two obtuse (rarely acute) tubercles. Merus twice as long as broad, bearing acute tooth on superodistal margin. Small chela varying from 2.4 to 2.6 times as long as broad; merus similar to that of large chela but slightly more slender.

Carpal articles of the second leg with a ratio: 10:2:2:2:5.

Third leg with merus varying from 3.2–4.1 times as long as broad. Carpus with superior margin projecting as rounded tooth, inferior margin armed with spine. Propodus varying from 4.7–7.0 times as long as broad and bearing 6–10 spinules on inferior margin. Dactylus triunguiculate; middle ungius usually wider at base than superior ungius, but about the same length; notch between superior and middle ungius usually "V"-shaped and acute at apex. Inferior unguis less produced, at times not set off from inferior dactylar margin, varying from acute to a right angle. Notch between inferior and middle unguis usually a rounded "U"-shape.

Telson with posterolateral corners usually strongly projecting and acute, often almost as long as outer spinule of posterior pair, but at times with projection minimal. Spines on upper surface varying from large and heavy to small and short.

Discussion: Like many other synalpheids, the specimens in the *S. fossor* complex appear to be variable and the group has been divided into a series of species and subspecies; however, the species, or series of species, has not been common in the collections of previous workers and the references are limited. Below are annotations on all references.

S. fossor was originally described by Paulson from the Red Sea on the basis of sixteen specimens; his description does not emphasize many of the characteristics now considered to be of taxonomic importance, but he supplied seven small but valuable figures. (One point in his descripton needs clarification: he described the dactylus of the third leg as follows: "the internal surface is very concave, and the dactylopodite is spoonlike with prominent edges and has claws" (Por's translation, 1961: 109). This description especially when combined with the specfic name, *fossor,* which also could have reference to an excavate or "spoonlike" condition, might imply that the dactyls were excavate like some species of the Rapax group of the genus *Alpheus.* However, we have obtained some topotypes from the Red Sea which agree with Paulson's description on all other characteristics; these show the dactyls of the third to fifth legs to be compressed, with the only "spoonlike" characteristic to be the outline from the first to third unguis in lateral profile; there is no spoonlike excavation (*see* fig. 16s, t).

The next reference to the complex was that of De Man in 1897 to "*Alpheus* sp. varietas B" based on a single specimen from Atjeh in the Java Sea; in 1911 he placed this species under *S. bakeri stormi.*

In 1905, Coutière made the first report upon *S. fossor,* based on two specimens from the Maldives (p. 872). He remarked on what he thought was a difference between these two specimens and the description of Paulson in the

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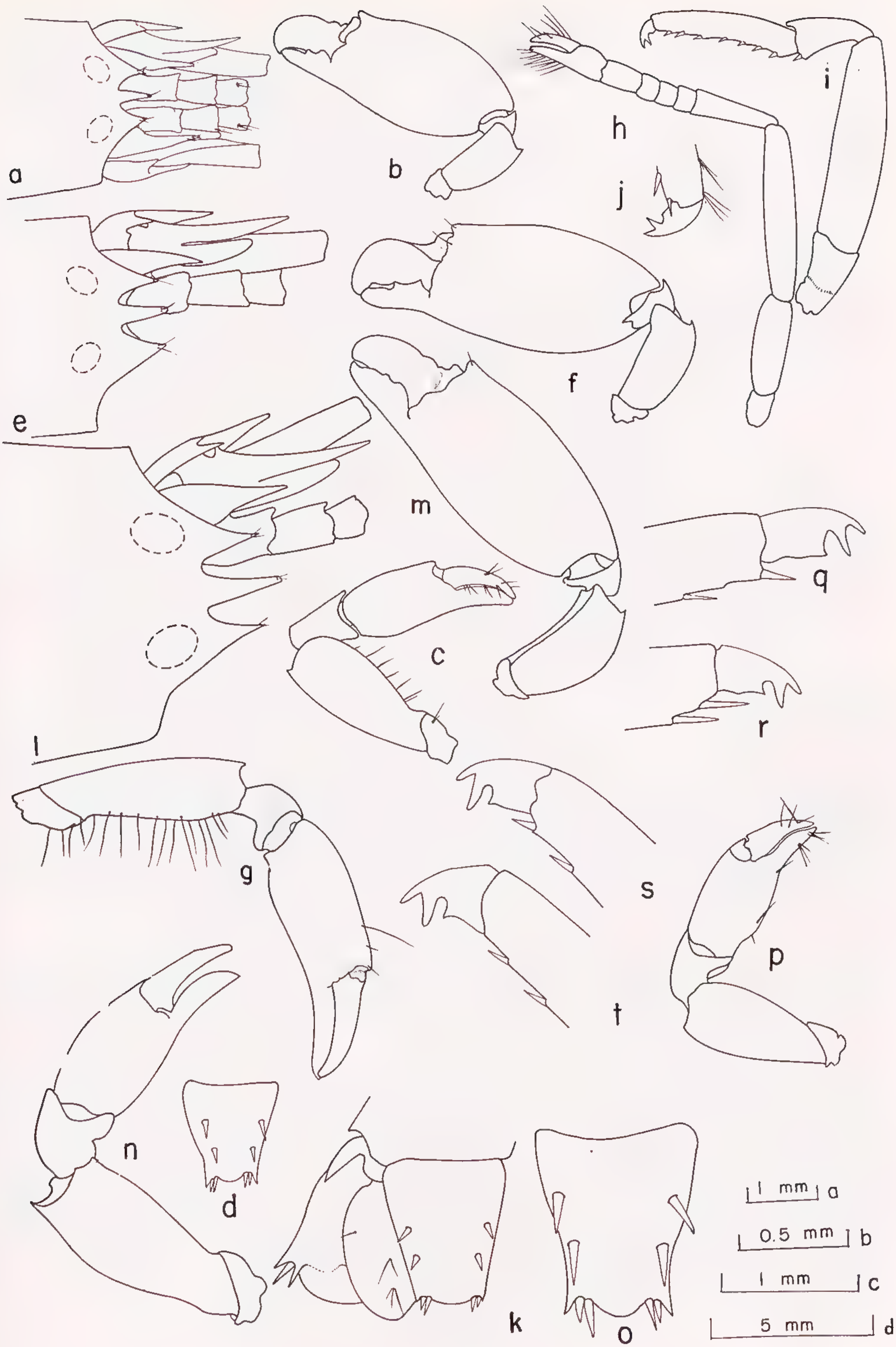
OPPOSITE

Fig. 16.—*Synalpheus fossor* (Paulson). 14 mm female from BAU 25: a, anterior region; b, large cheliped, outer face; c, small cheliped; d, telson. 17 mm male from BAU 40: e, anterior region; f, large cheliped, outer face; g, small cheliped; h, second leg; i, j, third leg and dactylus k, telson. 24 mm male from AME 4499: l, anterior region; m, large cheliped, outer face; n. small cheliped; o, telson. 12 mm male from Naifaro Reef, Maldive archipelago: p. small small cheliped; q, r, dactyls, third and fourth legs. 20 mm male from Naifaro Reef: s, t, dactyls, third and fourth legs. a, c, d, e, g, h, i, k, l, n, o, p, scale a; q, r, s, t, scale b; j, scale c; b, f, m scale d.


a
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l
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s
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n
d
k
o
1 mm a
0.5 mm b
1 mm c
5 mm d

curvature of the dactyls of the third legs in the region of the ungui. We have re-examined his two specimens through the courtesy of the Muséum National d'Historire Naturelle, Paris and have figured the dactyli of the third and fourth legs of both of his specimens (fig. 16 q, r, s, t); we find no great differences between these specimens and the topotypes referred to above. We should add that his specimens did not have the fringe of setae on the margins of the rostrum shown in his fig. 6; instead there were a few setae on the tip. Coutière in 1908 (*op. cit.*, p. 197) gives some proportions (presumably from the Maldive specimens) in his description of *S. trionyx*.

In 1908, Coutière (*op. cit.*) described *S. bakeri* from South Adelaide on the basis of two specimens (the description, also without figures, was republished in a condensed form in 1909:91). Unfortunately Courtière compared the specimens to *S. triunguiculatus* (Paulson) instead of *S. fossor*, to which they were more plainly related. Since the original description no specimens have been assigned to this species.

In 1911 De Man erected the variety, *S. fossor* var. *propinqua* (p. 250) on the basis of eight specimens from Indonesia and one from Pearl Banks, Sulu Archipelago. Those he compared to Coutière's two specimens which he had borrowed and separated the two forms "by the more slender shape of the meri and propodi of the three posterior legs and by the larger number of propodal spines." He also created *S. bakeri stormi* (*op. cit.* p. 253) on the basis of six other specimens which he separated from *S. bakeri* by "slight differences".

Tattersall in 1921 (*loc. cit.*) reported on 14 specimens from the Sudanese Red Sea as *S. fossor* and suggested that his specimens were intermediate between Paulson's species and De Man's variety *propinqua*.

In 1938, Lebour (Proc. Zool. Soc. Lond. B, 108: 651) described a species from Madras "associated" with the ascidian *Herdmania pallida* (Michaelson) (now *H. momus* (Savigny)) under the name of *S. herdmanae*. This species is plainly related to the *S. fossor* complex, but can be separated by "a small extra protuberance dorsally beside the three hooks" on the dactylus of the third to fifth legs. In view of this difference and its unique symbiotic relationship, this species is accepted and not further discussed.

S. fossor was recorded without comment by Coutière in 1921 (Trans. Linn. Soc. Lond. 17 (4): 416) from Chagos and similarly by Calman in 1939 (British Mus. John Murray Exped. Sci Rep. 6 (4): 208) from the Red Sea.

For our review of this complex we have a moderate sized collection: fifty-six specimens from various parts of Australia, thirteen from the southern Philippines, two from Thailand, and eleven from the Red Sea; the species did not appear in any of our central Pacific collections. Some of these specimens were reported as coming from sponges, others as free living in coral heads. These specimens we have compared to criteria used to separate the nominal species and subspecies as derived from both the various descriptions and characteristics taken from the figures. The results are given in Table III. with a comparison to the variation found in Australian specimens.

Table 3. Variation in nominal species of the Synalpheus fossor *(Paulson) complex*

Characteristic	*S. fossor*	*S. fossor propinqua*	*S. bakeri*	*S. bakeri stormi*	Australian specimens
Length of rostrum to antennular articles.	Past middle of first.	Same as *S. fossor*.	Middle of second	End of first ..	Middle of first to first quarter of second.
Length, of orbital teeth to rostrum.	Equal	Slightly shorter.	0·7 length ..	0·66–0·75 length.	0·66 to equal.
Length, of squame to antennular articles.	To end of second.	To middle of third.	Not given ..	Almost to end of third.	From end of second to end of third.
Length, of lateral spine of scaphocerite to antennular articles.	To end of third.	Just past end of third.	Slightly past end of third.	Same as *S. bakeri*.	From end of third to length of third beyond.
Length/breadth large chela ..	2·7 (from plate).	3·2 (from plate).	2·5	2·75	2·5–2·8.
Tubercle above datylar articulation, large chela.	One	One acute tooth and one obtuse tubercle.	Unarmed ..	Solitary small conical tooth.	From completely lacking to two small tubercles.
Length/breadth small chela ..	Not figured or given.	3·0 (from plate).	Not figured or given.	4·0	2·4–3·6.
Length/breadth merus third leg ..	3·5 (from De Man).	2·8–3·6	3·5	4·0	3·2–4·1.
Length/breadth propodus third leg	5·6 (from plate)	4·4–5·2	Not figured or given.	6·5–7·0	4·7–6·0.
Spines on propodus, third leg ..	7..	9 (from plate) ..	Not given ..	7..	6–10.
Size of outer angles, telson ..	Long	Short	Like *S. fossor* ..	Short	From short to long.
Size of dorsal spines, telson ..	Large	Medium ..	Not given ..	Small	From small to large.

Most of the characteristics used in the separation of the named members of the complex are those found to be variable in so many other species of *Synalpheus;* here too they were also found to be variable. In most cases the variation noted encompassed the differences that had been used to separate the members of the complex. In a few cases, as the rostral length in *S. bakeri* or the propodal breadth of the third legs in *S. bakeri stormi,* the proportions exceeded the range that we found. However, in these cases our ranges was so great that the significance of this further extension was questionable (for example in the propodus we found variation in the length-breadth ratio from 4.7–6.0, and De Man reported variation from 6.5–7.0). We therefore put all of the nominal species and subspecies except *S. herdmaniae* into synonymy under *S. fossor*. We should remark that the broad patterns in variation that we report are not found in all geographically separated poullations. Thus the sample we obtained from Thursday Island showed rather restricted variation, and could be separated from the samples we obtained from the Whitsunday Group by the two processes above the dactylar articulation, and large spines on the telson. Because of this regionality we originally considered the erection of geographically separated subspecies, but discarded the idea when we found that the Torres Straits specimens were quite like those from the Red Sea and the Whitsunday specimens approached De Man's variety *propinqua* from Indonesia; moreover, the specimens from other areas of Australia varied in more inconstant patterns. Perhaps further study with much more extensive collections will indicate reliable subspecific differences; they are not so indicated by these collections.

Biological notes: Most specimens were apparently collected from dead coral, although undoubtedly some were within sponges in the dead coral. The pair of specimens from BAU 40 were found living in an orange-red membranous sponge and were salmon pink, their colour close to that of their host. Our specimens ranged in size from 10–25 mm.

Australian distribution: From off southwest West Australia to Shark Bay; Darwin and Thursday Island on the North Coast and on the East Coast from Port Douglas to Southport, southern Queensland; in South Australia from Spencer's Gulf and Kangaroo Island.

General distribution: Red Sea; Maldive Archipelago; Indonesia; Thailand; Philippines.

Synalpheus haddoni Coutière

Fig. 17

Synalpheus laevimanus haddoni Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411, figs.

Synalpheus haddoni Coutière, 1909, Proc. U.S. natn Mus. 36 (1659): 10.

Original description, our translation: "This is the first mention that has been made of the presence of *Synalpheus laevimanus* in the Pacific, the species that has long been known as peculiar to the Mediterranean. I have remarked previously that *S. spinifrons* (H.–M. Edwards) from the coasts of Chile was very probably this species, that *S. laevimanus longicarpus* Herrick, extremely common on the Atlantic coast of America, was slightly different, and finally, I have described a new variety of *S. laevimanus parfaiti* coming from Annobon [Dutch Guiana, Bull. Soc. ent. Fr. 1898 (8): 189]. There is no doubt about the close relationship which unites the Mediterannean species with two specimens from the Torres Straits I have examined. The tridentation of the frontal margin, whose tips are short and close together, the form and proportions of the stylocerite, the strong spiny armature of the antenna, the total absence of the antennular scale, the form of the large chela, whose anterior palmar border carries a strong spine, the proportions of the segments of the carpus of the second legs [the proportions] of the third, fourth and fifth legs, the form of their dactylopodites, are many of the identical characteristics of specimens from the two regions. The differences which one can bring up are the following: the antennular peduncle, on the typical specimens and also in the preceding varieties always passes markedly the antennular peduncle (in general by the length of the distal article past that article). On the two specimens in question this length does not exceed one-third of the length of the distal antennular article. Of the two ungui which terminate the dactyl, the posterior is scarcely stronger than the anterior, whereas in the typical specimens one observes a rather notable difference between the two hooks. Finally the distal spines of the telson are practically equidistant, and those of the superior face are longer than ordinary. But these are characters subject to quite extensive variations, however in the typical *S. laevimanus* as well as the varieties *longicarpus* and *parfaiti* they justify at most the establishment of a new varity *haddoni*. Finally it is necessary to remark that the two specimens examined are young (the larger, a female carrying 6–7 eggs, is not more than 10 mm in length) and the differences here observed will be diminished without doubt by the examination of a larger series of specimens. 1 sp. female, 1 sp., male (?) (the latter is only 4 mm long).—Sabai Channel, Torres Straits."

We are at loss as to how to handle Coutière's change of status in his 1909 publication, for the name was merely listed in a table without comment but with a (?). However, he did not only remove the species from *S. laevimanus* itself, but also from his Laevimanus Group, placing it in the Biunguiculatus Group. We believe that the raising of the name *haddoni* to specific rank, and the change of group is logical, for no members of the Laevimanus Group have penetrated into the Indo-Pacific faunal realm, and *S. laevimanus* is, as Coutière has stated, a species typical of the Mediterranean. Therefore we are tentatively accepting the 1909 designation of the form as an independent species.

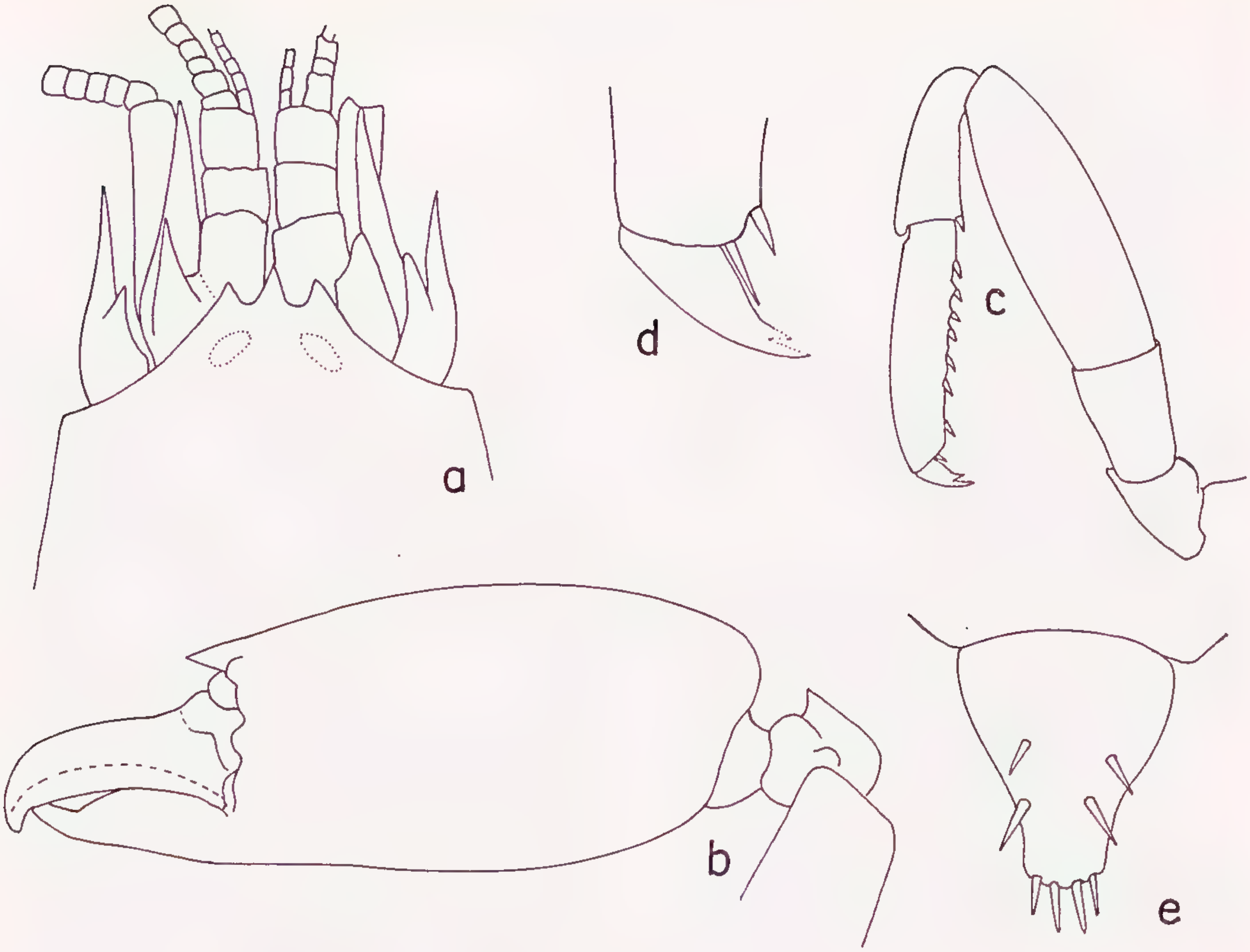


Fig. 17.—*Synalpheus haddoni* Coutière (after Coutière). 10 mm ovigerous female from Torres Straits. a, anterior region, dorsal view; b, large cheliped, outer face; c, d, third leg and dactylus; e, telson.

We have no specimens approaching this species, but we list it as there could be no doubt about the authenticity of the record and characteristics of the species, in particular, the reduction of the rostrum, orbital teeth and antennal squame, and the unique character of the telson and its armature. These characteristics insure that it has not been confused with any other Australian species so far reported.

Synalpheus coutierei Banner

Fig. 18 a–i

Synalpheus coutierei Banner, 1953, Pacif. Sci. 7 (1): 36; Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 62, fig. 20.

Alpheus biunguiculatus De Man, 1888a, Arch. Naturgesch. 53 (1): 502, pl. 21, fig. 6. Bate, 1888, Challenger Rept. 24: 562, pl. 101, fig. 4.

Synalpheus biunguiculatus Coutière, 1898g, Bull. Soc. ent. Fr. 1898 (11): 232, figs 1–4 [Arafura Sea, N. W. Australia]; 1905a Fauna and Geog. Mald. and Laccad. 2 (4): 873, pl. 71, fig. 8.

Synalpheus biunguiculatus var. *exilipes* Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 874, fig. 10. Balss, 1921, K. Svenska Vetensk. Akad. Handl. 61 (10): 9 [Cape Jaubert].

Synalpheus exilipes Johnson, 1962a, Bull. natn. Mus. St. Singapore 30: 51.

[*Nec*: *Synalpheus biunguiculatus* (Stimpson), 1861, Proc. Acad. nat. Sci. Philad. 1860: 31.]

Additional Australian Records (older records as *S. biunguiculatus*):
Ortmann, 1894, Denkschr. med. naturw. Ges. Jena 8: 14. Thursday Is.
Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411. Torres Straits.
McNeill, 1968, Gt Barrier Reef Exped. Sci. Rept 7 (1): 17; Low Isles.

Specimens examined: 1 specimen from AM 85; 4, AM 140; 1, BAU 10; 1, BAU 37.

Diagnosis: Rostrum narrow with tip reaching to near middle of first antennular article. Orbital teeth more than twice as broad at base as rostrum; length almost equal to rostrum. Tips of rostrum and orbital teeth rounded, bearing one or two setae. Rostral base with orbitorostral process.

Visible part of first antennular article 1.5 times longer than second; second article 1.5 times as long as broad and a little longer than third. Stylocerite reaching to middle of second antennular article. Scaphocerite with squamous portion narrow, and reaching to middle of third antennular article; lateral tooth reaching to past end of antennular peduncle. Carpocerite 4.2 times as long as wide when viewed ventrally, reaching length of third antennular article past that article. Inferior spine of basicerite subequal in length to stylocerite, superior tooth acute and prominent.

Large chela 2.5 times as long as broad, with fingers occupying distal 0.3 Superior margin of palm terminating in subacute tooth above dactylar articulation, second shorter tubercle adjacent medially. Dactylus heavy, longer than fixed finger. Merus two times as long as broad with angular superodistal tooth. Small chela 2.7 times as long as broad, fingers shorter than palm. Margin of outer face of dactylus carrying 8–10 follicles with one or two stiff setae. Lateral face of palm near dactylar articulation also bearing patch of stiff setae. On inner face, margins of both dactylus and pollex bearing stiff setae that cross in regular fashion. Carpus varying from 0.2–0.4 times as long as chela, inferodistal margin bearing 3–4 stiff setae. The inferoexternal margin of merus bearing fine setae placed at random along its entire margin. The inferointernal margin glabrous. The inferior margin of the ischium bearing a row of evenly spaced fine setae.

Carpal articles of the second leg with a ratio 10:2:2:2:4; articles 2–4 broader than long.

Merus of third leg 3.3 times as long as broad, inermous. Carpus 0.4 as long as merus; superior margin extended into an obtuse tooth; inferior margin with short distal spine. Propodus almost as long as merus, bearing on inferior margin seven spines and a pair distally. Dactylus biunguiculate, superior unguis a little longer than inferior unguis, region between ungui "U"-shaped.

Telson 2.4 times as long as broad at the posterior margin, posterolateral angles right angles.

Discussion: This species was considered by De Man (1888a *et seq.*) and Coutière (1898g *et seq.*) to be the same species that Stimpson described as *S. biunguiculatus* from the Hawaiian Islands. As the species they recognized did not occur in Hawaii, in 1953 we described a neotype for *S. biunguiculatus* and conferred the name *S. coutierei* upon the species described by De Man and Coutière. At that time we did not consider the two varieties that Coutière described in 1905, *S. biunguiculatus exilipes* and *pachymeris*. The latter form was subsequently raised to specific rank by De Man (1911: 199) and has been accepted. In 1956, we identified some specimens from the Marianas as *S. coutierei exilipes,* but with doubts as to the validity of the subspecies for even in that small collection we found variation in the proportions considered by Coutière to be of value in the separation of the subspecies. Johnson (1962a) working with Malayan specimens raised Coutière's variety *S. biunguiculatus* [*sic*] *exilipes* to specific rank, without further comment.

We have reviewed not only the Australian specimens but also specimens from other collections for the validity of the separation of the variety *exilipes* from the parent species. As has often been found, the characteristics used by Coutière for the separation of his five specimens from the Maldives into two subspecies are variable and the subtle differences in proportions used by Coutière, unreliable. We also question the separation of *S. bispinosus* De Man from this species (*see* p. 180).

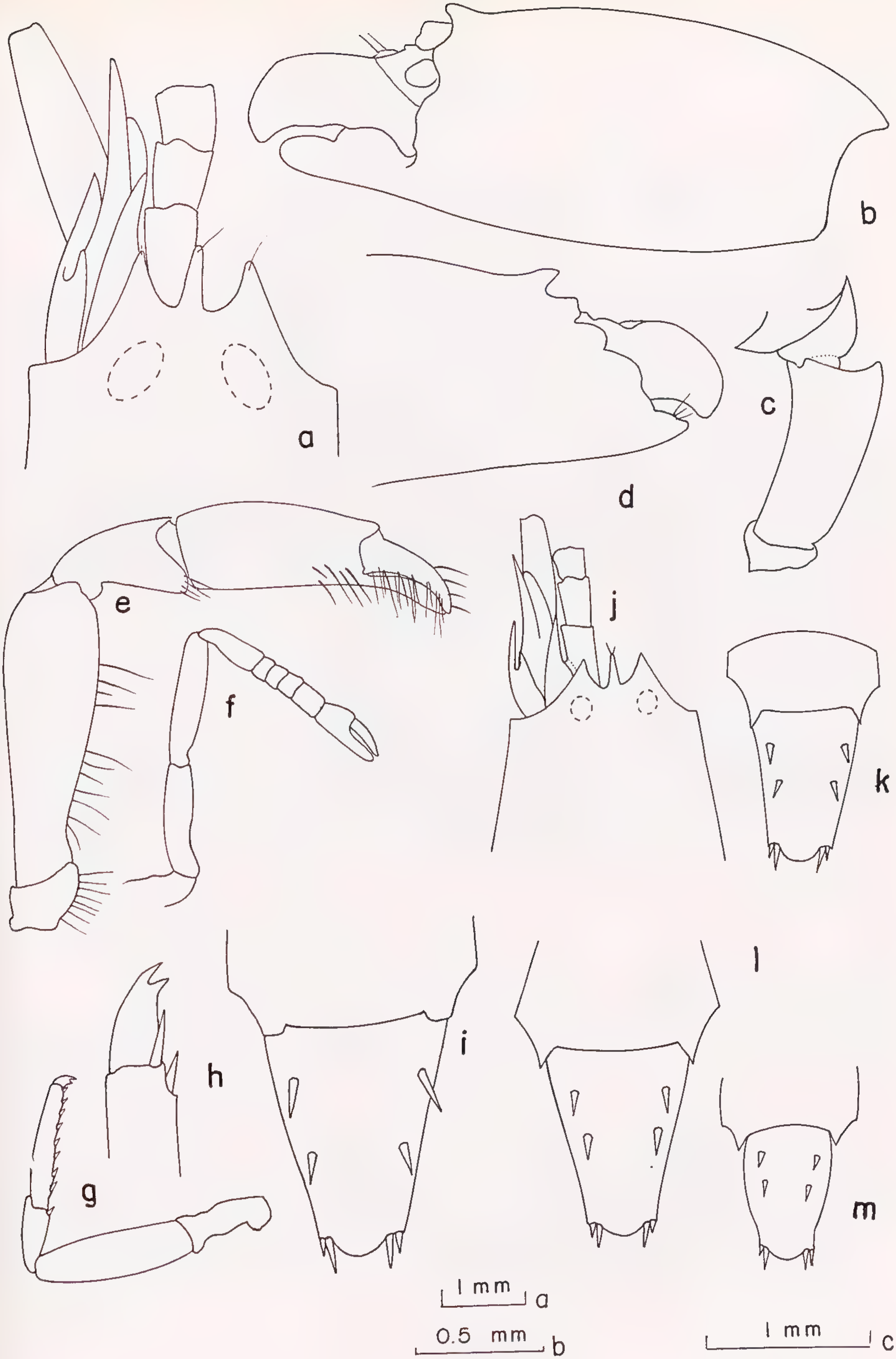
Biological notes: This species has been collected in shallow water from heads of dead coral. Coutière reported sixty specimens from Djibouti collected from heads of the coral *Stylophora* spp. in which it was living in company with *S. triunguiculatus* (Paulson). He also reported many specimens were found living among the settling growth on buoys (1898g: 232). In Thailand we found it living in a sponge. We also have on hand some large speimens from the Indian Ocean that were dredged at 77 metres. The Australian specimens range from 9–23 mm.

Australian distribution: The specimens in the present collection came from the northwest of Western Australia, Darwin, Torres Straits and north and central Queensland, a range that includes those previously reported.

General distribution: From the Suez Canal and Persian Gulf south to Mozambique and eastward across the Indo-Pacific, occurring in most investigated archipelagoes, but not in Hawaii or the Societies. It has not been reported from Japanese waters; however, it has passed the Eastern Pacific barrier to Clipperton Island.

OPPOSITE

Fig. 18.—*Synalpheus coutierei* Banner. 11 mm male from BAU 37: a, Anterior region, dorsal view; b, c, large chela and merus, outer face; d, distal region of chela, inner face; e, small cheliped; f, second leg; g, h, third leg and dactylus enlarged; i, telson. *Synalpheus bispinosus* De Man. 10 mm male from AM. 140: j, Anterior region, dorsal view; k, telson. 20 mm female from AM 85: l, telson. 12 mm female from BAU 25: m, telson. b, c, d, e, f, g, j, k, l, m, scale a; h, scale b; a, i, scale c.


a
b
c
d
e
f
g
h
i
j
k
l
m
1 mm a
0.5 mm b
1 mm c

Synalpheus bispinosus De Man

Fig. 18 j-m

Synalpheus bispinosus De Man, 1910b, Tijdschr. ned. dierk. Vereen. 11 (4): 302; 1911, Siboga Exped. 39a[1] (2): 280, fig. 54.

Specimens examined: 1 specimen from AM 140; 1, BAU, 25; 1, WM 30–65.

Diagnosis: Characteristics fall within the range of variation of *S. coutierei* Banner (p. 343) except that the posterior margin of the sixth abdominal segment is produce into acute teeth, one on either side of the articulation of the telson.

Discussion: We are reporting these specimens as *S. bispinosus* with considerable doubt, for in all characteristics except the lateral teeth on the posterior margin of the sixth abdominal segment they are indistinguishable from *S. coutierei.* Even De Man in his original description remarked on the similarity of *S. biunguiculatus exilipes* Coutière (=*S. coutierei*). However, of all specimens available of the latter species none showed other than the normal rounded condition of the posterior margin of the sixth abdominal tergum, and none of these showed other than well-developed and acute teeth. Moreover, the two forms were not collected together. Therefore we accept the separation at least until further collections are available.

Biological notes: This species has been collected at depths between 6 and 100 feet. They ranged in sizes up to 15 mm in length.

Australian distribution: Our specimens were collected in the Dampier Archipelago, Darwin and the Torres Straits.

General distribution: De Man's specimens were from Indonesia; we have some as yet unreported specimens from the Red Sea and the Southern Philippines.

Synalpheus ancistrorhynchus De Man

Fig. 19

Synalpheus ancistrorhynchus De Man, 1909a, Tijdsch. ned. dierk. Vereen. 11 (2): 124; 1911, Siboga Exped. 39a[1] (2): 267, fig. 47.

Specimens examined: 2 specimens from AC S2; 6, AM 3; 5, AM 85; 2, AM 123; 5, AM 137; 1, AM P 2577; 2, BAU 53; 1, BAU 54; 1, WM 77–65.

Diagnosis: Rostrum and orbital teeth short, equal in length; reaching to first quarter of visible part of first antennular article; wide at their bases, curved upwards at their tips, tips bearing short stiff setae. Rostral base with orbitorostral process.

Visible part of first antennular article and second article subequal, third article a little shorter than second. Stylocerite reaching first quarter of second antennular article. Squamous portion of scaphoceute narrow, reaching to end of second antennular article, lateral spine reaching to near end of third antennular article; cleft between lateral spine and squamous portion deep, reaching proximtiy to first antennular article. Carpocerite the length of third article past that article. Inferior spine of basicerite almost as long as stylocerite, superior spine acute, about one-third as long as inferior spine.

Large chela 2.5 times as long as broad, superior margin projecting as rounded tooth above dactylar articulation, fingers half as long as palm. Merus two times as long as broad, distosuperior margin slightly projected, subacute, other distal margins rounded. Small chela 3.6 times as long as broad, fingers a little shorter than palm. Superior margin of palm slightly projecting distally. Dactylus slightly broadened, bearing a row of curved setae, usually two hairs per follicle, placed laterally. Lateral margins of dactylus being short stiff setae. Merus 1.4 times as long as broad, superodistal margin rounded.

Second leg stout, carpal articles with a ratio 10:2:2:2:5; three middle articles each broader than long.

Merus of third leg 3.5 times as long as wide, usually bearing on distal portion of inferior margin 2-3 small spines. Carpus 0.3 as long as merus, armed with inferodistal spine. Propodus half as long as merus and bearing eight spines on its inferior border, two distally. Dactylus biunguiculate, superior unguis about 1.5 times longer than inferior unguis, but thinner at base.

Telson, varying, usually about twice as long as broad at posterior margin. Laterial margins may have subterminal constriction. Posterolateral angles produced into strong teeth which are much longer than the slightly arcuate posterior margin, but shorter than the adjacent spines. Spines of posterior margin large, almost equal in length. Spines on dorsal surface of telson large, as long as, but heavier than spines on tip. Outer uropod with partial, non-functional distal articulation.

Discussion: We found some variation in our 20 specimens. The spines may be lacking on the merus of the third legs, but in those the usual place of the spines carried small patches of setae. The ungui of the dactyli of the third legs varied in relative lengths (fig. 19 g, m). The telson was variable in the subterminal constriction, in the size of the posterolateral teeth and in the proportions of both the dorsal and terminal spines (compare figs 19h-k). In some specimens the articulaton on the outer uropod was visible, but did not constitute a line of flexion.

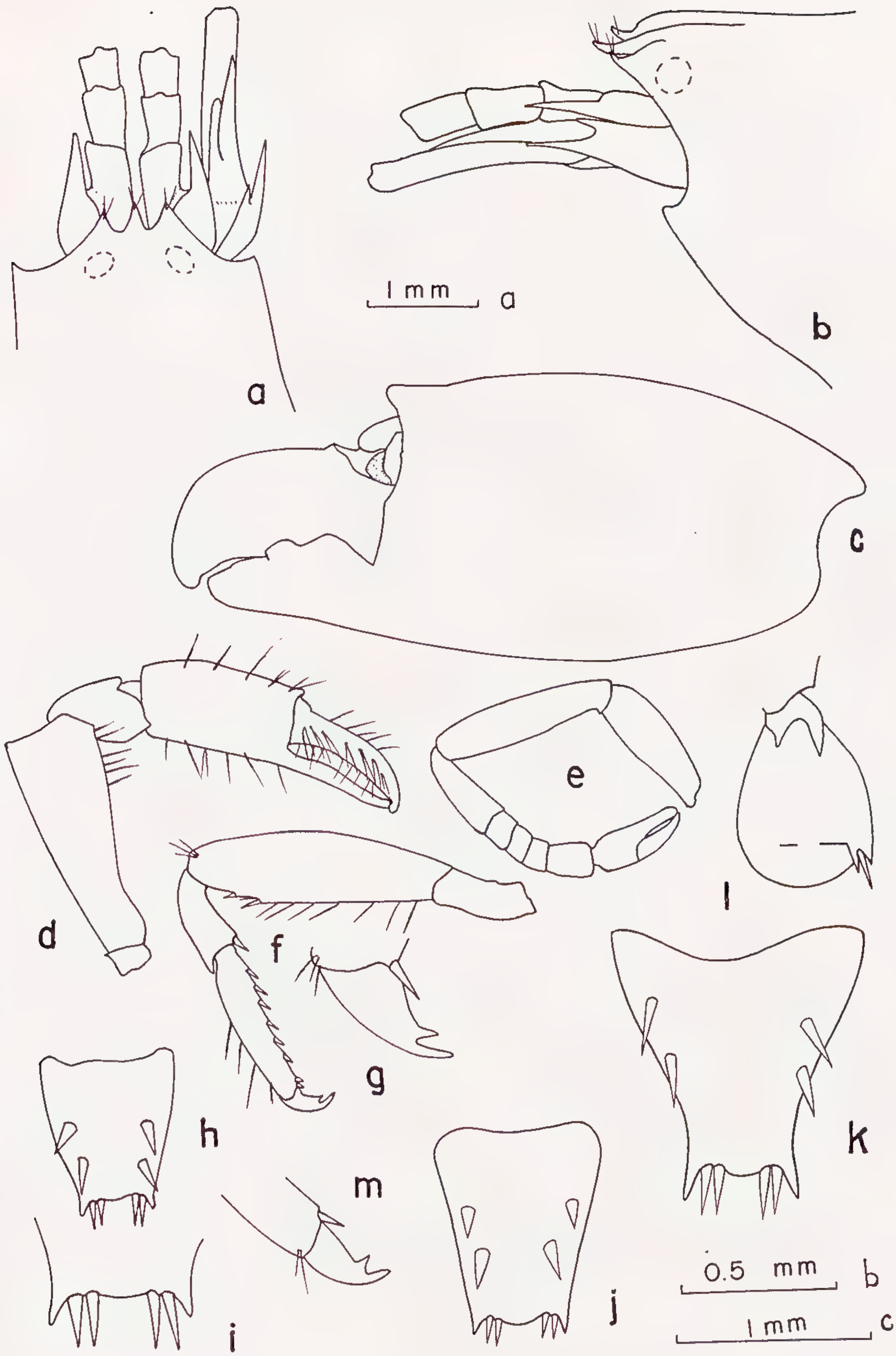
As De Man pointed out, this species very closely resembles *S. hastilicrassus* Coutière. However, the much shorter orbital teeth, the stouter thoracic legs, and usually the spines on the meri of the third legs clearly separated the two. De Man states (without a figure) that there is a small tooth on the superior margin of the merus of the large chela; in these specimens it is a minor projection.

Biological Notes: This is not a large species, the largest one in our collection being 15 mm long. The species has been dredged from 21 fathoms in Western Australia and has been found in coral heads in Queensland.

Australian Distribution: This species has been collected in Western Australia between 18° and 30° S., at Darwin and at Heron and Masthead Island off Queensland.

General Distribution: This is the first report of the species since De Man's original report of his two specimens from Indonesia.

Fig. 19.—*Synalpheus ancistrorhynchus* De Man. 14 mm male from AM3: a, b, anterior region, dorsal and lateral view; c, large chela, inner face; d, small cheliped, outer face; e, second leg; f, g, third leg and enlargement of dactylus; h, i, telson and enlargement of posterior region. 12 mm male from BAU 54: j, telson. 11 mm female from WM 77-65: k, telson. 10 mm male from BAU 54: l, uropod. 12 mm female from AM 137: m, dactyl of third leg. a, b, c, d, e, f, h, l, scale a; g, m, scale b; i, j, k, scale c.



a
b
1 mm a
c
d
e
f
g
h
i
j
k
l
m
0.5 mm b
1 mm c

Synalpheus lophodactylus Coutière

Fig. 20

Synalpheus lophodactylus Coutière, 1908a, Bull. Soc. Philomath, Parish IX, 11 (5): 197; 1921, Trans. Linn. Soc. Lond., Zool. Lond. II, Zool. 14, 17: 417, pl. 61, fig. 11. Banner, 1957, Pacif. Sci. 11 (2): 195.

Specimens Examined: 12 specimens from AM 419: 18, AM P 12426; 1, BAU 33; 2, BAU 43; 2, BAU 44; 1 specimen each from CS 1, 3, 4, 11, 12, 18; 3, WM 82-65; 3, WM 140-65; 1, WM 175-65; 11, WM 267-65; 9, WM 251-78-32; 13, WM 9991; 10, WM 10380; 1, WM 10410; 40, WM 10467; 35, WM 10472; 51, WM 10481; 4, WM 10487; 34, WM 10591/92.

Diagnosis: The normal form of rostrum twice as long as broad at base, reaching end of visible part of first antennular article. Orbital teeth not as long as rostrum, but broader at base. Rostral base with orbitorostral process.

Visible part of first antennular article and second antennular article almost equal, third article a little shorter than second. Stylocerite reaching to end of first antennular article. Squamous portion of scaphocerite reaching past middle of third antennular article, lateral tooth reaching beyond antennular peduncle. Carpocerite 3.4 times as long as wide, reaching almost the length of third article past that article. Inferior tooth of basicerite reaching to middle of second antennular article, superior margin without projection.

Large chela 2.7 times as long as broad, distal end of superior margin of palm terminating into an obtuse tooth, tilted slightly upward. Merus three times as long as broad, distal angles inermous. Small chela three times as long as broad; superior surface of dactyl bearing a longitudinal brush of hairs, placed slightly laterally, extending almost full length. Carpus ranging from 0.25-0.50 times length of chela. Merus similar to that of large chela.

Carpal articles of second leg with a ratio 10:2:2:2:6, middle articles broader than long.

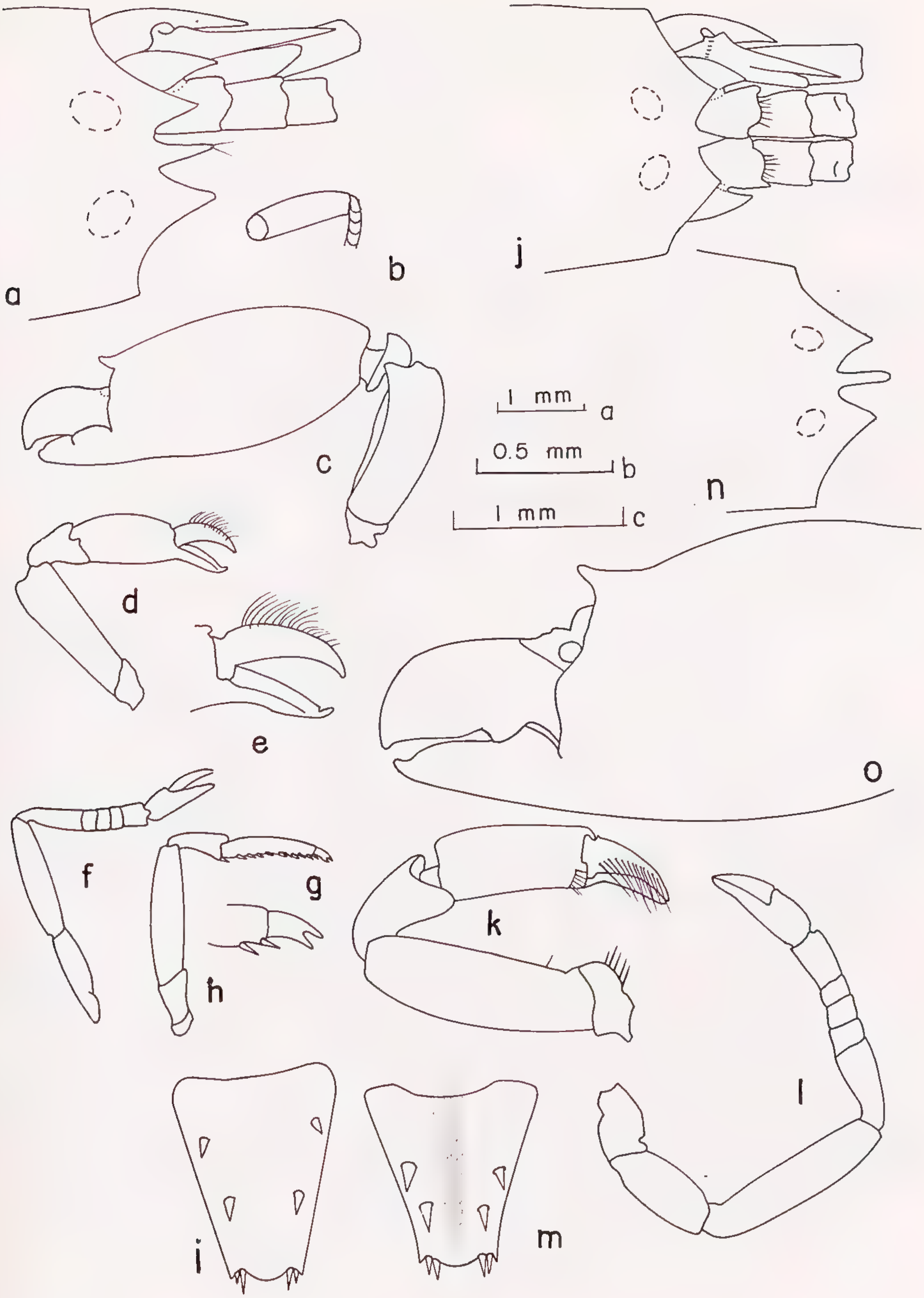
Merus of third leg inermous, 4.5 times as long as broad. Carpus 0.36 as long as merus; distal end of superior margin projected into a blunt tooth, inferior margin terminating in single spine. Propodus 0.6 times as long as merus, bearing on its inferior margin 9 movable spines and two distally. Dactylus biunguiculate, ungui of equal length, apex between ungui "U"-shaped.

Telson 2.2 times as long as broad at posterior margin. Posterolateral angles acute, about half as long as short lateral spine of distal pair. Tip of telson between spines slightly convex. Outer uropod without transverse articulation.

Discussion: We have examined the type at the Muséum d'Histoire Naturelle in Paris; Coutière figure (1921: pl. 61, fig. 11) is an excellent likeness, however, the small cheliped was missing. Our specimens agree well with Coutière's with a few exceptions. The inferior spine of the basicerite reaches

OPPOSITE

Fig. 20.—*Synalpheus lophodactylus* Coutière. 11 mm ovigerous female from BAU 44: a, anterior region, dorsal view; b, carpocerite; c, large cheliped; d, e, small cheliped, enlarged view of fingers; f, second leg; g, h, third leg and enlarged view of dactylus; i, telson. 12 mm male from AMP 12426: j, anterior region; k, small cheliped; l, second leg.; m, telson. 10 mm male from WM 275-65: n, anterior region, dorsal view. 22 mm male from CS 9: o, distal section of large chela. b, c, d, f, g, j, m, n, scale a; h, scale b; a, e, i, k, l, o, scale c.


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
1 mm a
0.5 mm b
1 mm c

to the middle of the second antennular article instead to the end of the first; in one specimen from BAU 44 it reaches to end of second antennular article. The brush of hairs on the superior surface of the dactyl of the small chela in our specimens extend from almost the articulation of the dactylus instead of appearing only in the distal section as in Coutière's specimen.

We found this also true for our specimen from Arno Atoll (1957: 196). We found variation in the length of the carpus of the small cheliped as mentioned above.

In collections from sponges in Western Australia we found notable variation. The extreme condition in the anterior region is shown in fig. 20j. In this form the rostrum and the orbital teeth were markedly shortened, the orbital teeth were relatively broader at the base; the antennules were stouter; the carpocerite was 3.0 times as long as broad instead of 4.0 as found in normal specimens. The first article of the carpus of the second leg was only 0.7 as long as the four following (fig. 20 l) while in the normal form the first article was almost equal to the four following. These characteristics were not constant in any geographical area, for example, in a single collection of fifty-one specimens from a single sponge the normal form, the extreme form and intermediates occurred. This does not appear to be more than the normal variations which are found so often in symbiotic synalpheids.

The differences between this species and its nearest relative, *S. hastilicrassus,* are subtle and the separation of the two species is difficult. The principle difference is that *S. lophodactylus* is a stouter species than *S. hastilicrassus.* In *S. lophodactylus* the stylocerite is always shorter than both the first antennular article and the outer tooth of the basicerite, while in *S. hastilicrassus* it reaches the middle of the second antennular article and is equal to the outer tooth of the basicerite. In *S. lophodactylus* the carpocerite is less than 4.0 times as long as broad while in *S. hastilicrassus* it is more than 4.0 times as long as wide. The tooth on the distosuperior margin of the palm of the large chela is tilted upwards in *S. lophodactylus,* but in *S. hastilicrassus* it is not. The second leg is stouter in this species, the first article being 2.5 times as long as wide at its distal end, while in *S. hastilicrassus* it is 3.5. Finally the posterior lateral angles of the telson in *S. lophodactylus* are not as strong as those for *S. hastilicrassus.* The outer uropod has a transverse articulation in *S. hastilicrassus.*

Biological notes: Of the 208 specimens in the collection all except 7 were taken from sponges, with a large number from sponges which has been carried to the beaches by storm waves in Western Australia. Of those not reported to be from sponges, 3 were dredged from 2 fathoms and 4 were taken from dead coral between 2–6 feet deep. The specimens ranged in size from 7–22 mm.

Australian distribution: In Western Australia specimens came from as far north as Dirk Hartog Is., but the majority were found in storm-carried sponges at Cottesloe, near Perth. One specimen came from Chinamans Reef, off Port Douglas, Queensland, and others came from the Whitsunday Group off Queensland.

General distribution: Chagos Archipelago, Indian Ocean; Marshall Islands.

Synalpheus hastilicrassus Coutière

Fig. 21

Synalpheus hastilicrassus Coutière, 1905a, Fauna and Geog. Mald. and Laccad, 2 (4): 875, pl. 72, fig. 12. De Man, 1911, Siboga Exped. 39a[1] (2): 263, fig. 45 [*partim*].

Synalpheus hastilicrassus (Coutière var.? De Man, 1911, Siboga Exped. 39a[1] (2): 264, fig. 45b [*partim*].

Synalpheus hastilicrassus acanthitelsoniformis De Man, 1920, Zoöl. Meded., Leiden, 5 (3): 108; 1922, Siboga Exped. 39a[4] (5): 29, fig. 14.

Synalpheus acanthitelsonis Coutière, 1905a, *loc. cit.* 2 (4): 875, fig. 13. De Man, 1911, *loc. cit.*: 256, fig. 46. Gravely, 1930, Bull. Madras Govt Mus. new ser. (nat. Hist.) 1 (2): 77, pl. 1, fig. 1. Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 58, fig. 18.

Specimens examined: 1 specimen from AM 137; 1, AM 258; 1, AM P 1966; 1, AM P 3566; 6, BAU 25; 2, BAU 27; 3, BAU 37; 4, BAU 38; 3, BAU 40; 1, BAU 42; 4, BAU 44; 3, BAU 48; 3, BAU 53.

Diagnosis: Rostrum slender, three to four times as long as broad at base, reaching variously from end of first antennular article to near end of second article. Orbital teeth directed straight forward, about 0.6 as long as rostrum, but much broader at base. Rostral base with orbitorostral process. Visible part of first antennular article subequal to second article; third article from half to almost equal length of second. Stylocerite reaching near middle of second antennular article. Scaphocerite with squamous portion reaching variously from middle to end of third antennular article. Lateral tooth of scaphocerite much longer, equal to or longer than carpocerite, carpocerite reaching past antennular peduncle by length of third article. Superior margin of basicerite usually truncate, inferior tooth subequal in length to stylocerite.

Large chela cylindrical, 2.7 times as long as broad; fingers about half length of palm. Palm terminating in subacute to acute tooth above the dactylar articulation, not upturned. Merus 2.2 times as long as broad, distosuperior margin usually without tooth. Small chela three times as long as broad, finger 0.4 as long as entire chela. Superolateral surface of dactylus bearing single row of inwardly curving setae, with one or two setae emerging from each follicle. Merus 3.8 times as long as broad; superodistal angle at times produced into acute tooth; inferointernal margin bearing row of setae.

Carpal articles of second leg with a ratio: 10:1:6:1:6:1:6:4.

Merus of third leg 4.5 times as long as broad, unarmed, carpus 0.6 as long as merus with superodistal margin projecting and subacute; inferodistal margin bearing small spine. Propodus 0.7 as long as merus, bearing eight spines on its inferior margin and two distally. Dactylus biunguiculate, 0.2 as long as propodus, ungui almost equal in length, superior unguis a little broader at base than inferior.

Telson 1.8 times as long as wide at arcuate posterior margin. Postero-lateral angles produced into acute teeth, usually long, reaching half or more than the length of the adjacent spine. Outer uropod with transverse articulation.

Discussion: Five nominal species and one subspecies of the Paulsoni group of *Synalpheus* have the posterolateral angles of the telson developed into large teeth. These are (in order of date of original description):

S. tumidomanus (Paulson)
S. hastilicrassus Coutière
S. acanthitelsonis Coutière

S. ancistrorhynchus De Man
S. hastilicrassus acanthitelsoniformis De Man
S. thai Banner & Banner

Also closely related is *S. lophodactylus* which Coutière (1909: 10) placed in the Biunguiculatus Group. For the separation of these two species see page 184.

Of the species listed above, three seem to be distinct: *S. tumidomanus* has only slight projections of the posterolateral angles (see p. 111) ; *S. ancistrorhynchus* has a much shorter rostrum and orbital teeth than the others, and usually bears 2–3 spines on the merus of the third legs; *S. thai* has extremely long posterolateral teeth, almost half as long as the telson proper. In the earlier paper (Banner & Banner, 1966b: 60) we questioned the validity of the separation of the other three species and subspecies. We now have more extensive collections so that we are better able to review their separation.

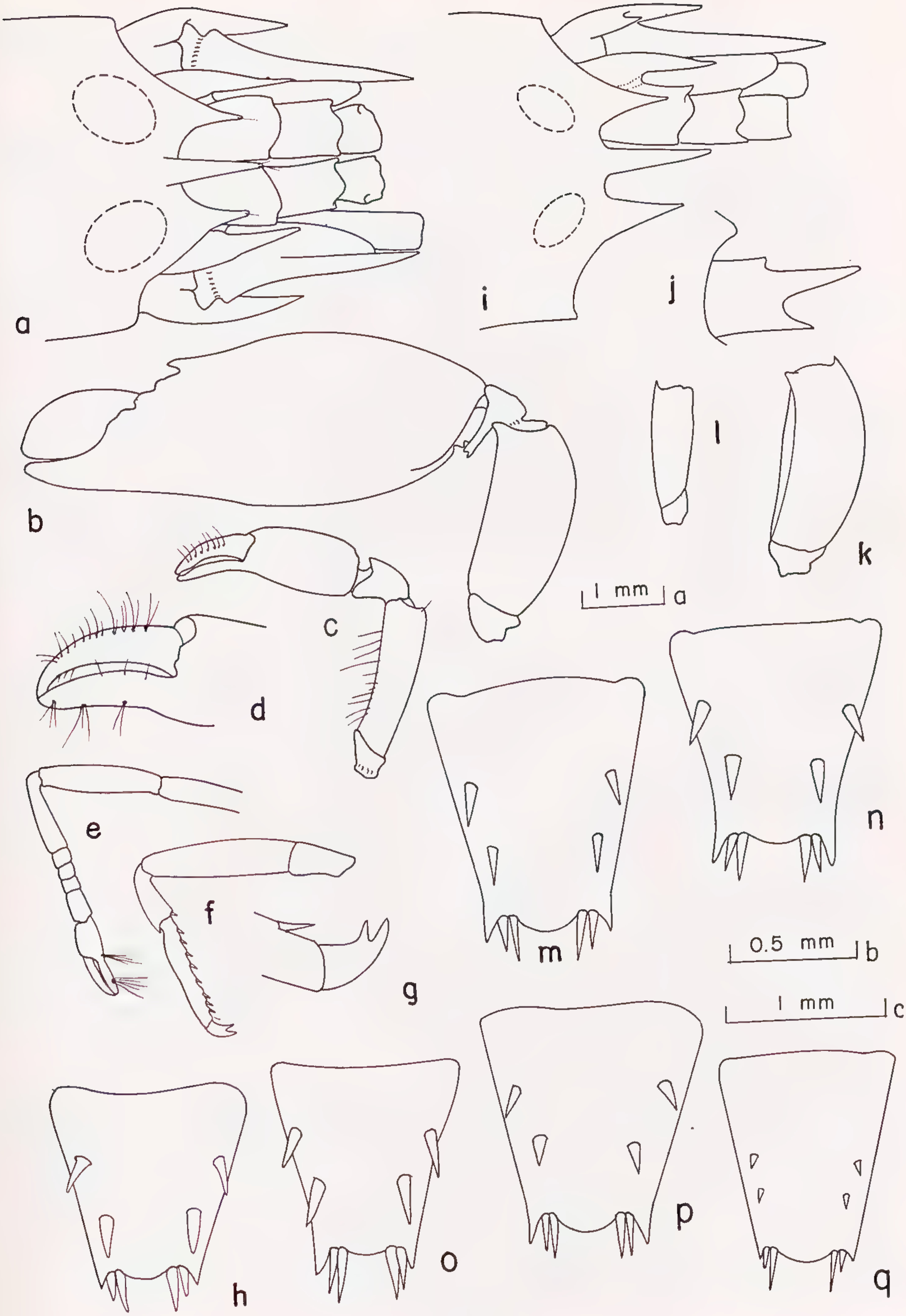
From these collections we have selected sixty specimens from our Malayo-Thai collection, twenty-one specimens from Queensland and twenty-nine specimens from the Sulu Sea in the southern Philippines. In the latter two collections, these were all the specimens in the collection that were completely intact and reasonably mature. We have assessed the variation of the five principal characteristics that have been used in the separation of the three nominal forms. The characteristics and the variations are given in table IV; it should be noted that we have,

Table 4. *Variation in* S. hastilicrassus

Characteristic	As described for			Percentage of specimens with characteristic		
	S. hastilicrassus	*S. h. acanthitelsoniformis*	*S. acanthitelsonis*	Malayo–Thai Collection 60 specimens	Queensland Collection 21 specimens	Sulu Sea Collection 29 specimens
				per cent	per cent	per cent
Superior tooth on basicerite	no	no	yes	45	5	0
Tooth on superodistal angle of merus, large cheliped.	no	missing	yes	94	19	78
Tooth on superodistal angle of merus, small cheliped.	no	no	yes	98	41	85
Posterolateral teeth of telson longer than midposterior arc.	no	yes	yes	10	43	96
Posterolateral teeth of telson longer than adjacent spines.	no	no	yes	0	0	0

OPPOSITE

Fig. 21.—*Synalpheus hastilicrassus* Coutière. 12 mm male from BAU 44: a, anterior region, dorsal view; b, large cheliped; c, d, small cheliped and enlarged distal section; e, second leg; f, g, third leg and dactylus; h, telson; 14 mm male from BAU 37: i, anterior region, dorsal aspect; j, basicerite of specimen; k, l, meri of large and small chelipeds; 14 mm male from Hong Kong: m, telson; 14 mm female from AMP 3566: n, telson. 11 mm female from Hong Kong: o, telson. 14 mm female from BAU 37: p. telson. 12 mm male from Hong Kong: q, telson. b, c, e, f, i, k, l, scale a; g, scale b; a, d, h, j, m, n, o, p, q, scale c.


a
b
c
d
e
f
g
h
i
j
k
l
m
n
o
p
q
1 mm a
0.5 mm b
1 mm c

for our tabulation, recorded each characteristic as all-or-none, but that in actuality the characteristic showed wide variation. Thus the tooth on the basicerite would be recorded as absent or present, but if present it would vary from a strong tooth to one almost non-discernible.

Supplementing the table are the drawings in figure 21. As can be seen from the wide variation both tabulated and depicted, none of the criteria used in separation, with a single exception, appear to be valid. The exception is the length relationship of the posterolateral teeth of the telson to the adjacent spines. In none of our specimens were the posterolateral teeth as long as the adjacent spines, a condition that characterizes *S. acanthitelsonis*, but there again was enough variation in the relative lengths that we believe with a larger collection this too would be within the range of variation. We therefore combine the three taxa under the name *S. hastilicrassus*.

There is some question about subspecific races of the species. Certainly the differences in percentages of specimens which bear any one characteristic in these three widely separated collections would indicate geographic and genetic isolation. However, to erect new subspecies, detailed studies on specimens from various parts of Indonesian waters (the Indo-Malayan subregion of Ekman, 1953: 18) would be desirable to determine the extent of variation in this probable center of distribution. Then the other possible geographic subspecies could be defined on their differences, not from one another, but from the presumable nominate stock. If so, then Coutière's species and De Man's variety may both be revived and given well-defined subspecific status. At present, the erection of new subspecies and the retention of the older names is not justified.

Two more variant forms of this species should be noted here to complete the discussion, although the specimens are from our Philippine collections. The first is similar to the form described by De Man as *S. hastilicrassus* Coutière var.? which he separated from the nominate form on the basis of the fingers of the large chela which are one-half, instead of one-third the length of the palm. We have two small females from the Sulu Sea with similar proportions in the large chela. We do not consider this difference in proportion to be specific or subspecific importance. It will be figured in our Philippine paper.

The second form is more perplexing, for in a male and a female collected from near Zamboanga almost all characteristics were those of *S. hastilicrassus*, but one has three, and other one, spine on the merus of the third legs. In this character, then, they are similar to *S. ancistrorhynchus* De Man. We at present regard the separation of *S. hastilicrassus* and *S. ancistrorhynchus* as firm, but these two specimens raise doubts. We will defer action until some future worker has larger and more adequate collections upon which to base his decision. These will also be figured in the Philippine paper.

Biological notes: This is not a large species, our largest specimen from Australia being 20 mm long. It has been dredged as deep as 90 metres and is found commonly inside coral heads in waters up to 5 metres. It has been found in sponges.

Australian distribution: Darwin, from Torres Straits in the north to Great Sandy Strait, south of Bundaberg, Queensland, on the east coast.

General distribution: Maldive Archipelago; Gulf of Manaar; Indonesia: Philippines*, Caroline and Marshall Islands; Fiji.

Synalpheus neomeris (De Man)

Fig. 22

Alpheus minor neptunus De Man, 1888b, J. Linn. Soc. Lond. 22: 272 [*nec A. minor* Rankin = *A. minus* Say; *nec A. neptunus* Dana].

Alpheus neomeris De Man, 1897, Zool. Jb. Syst. 9: 734, fig. 61 a, d, e [*partim*].

Synalpheus neomeris Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 869, fig. 1. De Man, 1911, Siboga Exped $39a^1$ (2): 212, fig. 24.

Synalpheus gravieri Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 870, fig. 2. Pearson, 1905, Rep. Govt. Ceylon Pearl Oyster Fish. Gulf Manaar 4 (24): 82. De Man, 1911, Siboga Exped. $39a^1$ (2): 216, fig. 25. Gurney, 1927, Trans. Zool. Soc. Lond. 22: 261, fig. 64 [larval development]. Banner & Banner, 1966b, Siam Soc. Mono. 3, p. 48, fig. 13. Miya, 1972, Publ. Amakusa Biol. Lab. 3 (1): 66, pl. 13.

Alpheus prolificus Ortmann, 1890, Zool. Jb. Syst. 5: 484 [*nec* Bate].

Alpheus neptunus Bate, 1888, Challenger Rept. 24: 563, pl. 101, fig. 2 [*nec A. neptunus* Dana].

Additional Australian Records:

Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411. Torres Straits.

Specimens examined: 2 specimens from AC S3; 1, AM 26; 2, AM 82; 2, AM 85; 7, AM 109; 1, AM 136; 1, AM 145; 2, AM 163; 2, AM 236; 2, AM 252; 1, AM 278; 1, AM 286; 1, AM 305; 1, AM 307; 2, AM 439; 1, AM G 1789; 1, AM P 3566; 1, AM P 3574; 1, AM P 11763; 2, MM 176; 1, WM 91–65; 1, WM 129–65; WM 304–65.

Diagnosis: Rostrum narrow, reaching to past middle of first antennular article. Orbital teeth triangular, a little shorter than rostrum, not tilted upward, bearing a few setae. Rostral base bearing orbitorostral process.

Second antennular article a little shorter than first, third a little shorter than second. Stylocerite reaching to middle of second antennular article. Squame of scaphocerite reaching to middle of third antennular article. Carpocerite reaching at least length of third article past that article. Inferior tooth of basicerite almost as long as stylocerite, superior tooth acute, nearly as long as orbital teeth.

Large chela 2.6 times as long as broad, bearing a tooth above the dactylar articulation that varies from a slight rounded projection to acute tooth. Fingers occupying 0.3 length of entire chela. Merus 2.0 times as long as broad with small projections terminally on both superior and internal margins. Small chela varying from 3.4–4.4 times as long as broad with fingers a little shorter than palm. Merus similar to that of large chela, but almost three times as long as broad.

Carpal articles of second leg with ratio: 10:1.6:1.6:1.6:3.0.

Third leg with ischium unarmed. Merus of third legs three times as long as broad, inner margin armed with 3–7 heavy movable spines.

Carpus 0.4 as long as merus, terminating on superior margin with heavy rounded tooth, on inferior margin with single spine. Propodus 0.8 as long as merus, slightly curved, and bearing nine spines on inferior margin and two distally. Dactylus biunguiculate. Superior unguis small, varying from one-fourth to one-third as thick at base, and from about one-third to one-half as long as inferior unguis.

Telson about 3.0 times as long as posterior margin is wide. Posterior angles not acute. Anterior pair of dorsal spines located posterior to middle.

Discussion: In 1897 De Man described *Alpheus neomeris* based on two specimens from the Mergui Archipelago, which in 1888 he called *A. minor neptunus* Dana, and on nine specimens from Atjeh, Sumatra. In 1905, Coutière with thirty-eight specimens from the Maldive Archipelago created a new subspecies, *S. neomeris streptodactylus* on the basis of the differences in the dactylus of the third leg. In 1911 De Man reexamined his previous specimens and decided: (1) that his Mergui specimens were the true *S. neomeris* which he re-described, and (2) that the specimens from Atjeh were of Coutière's subspecies, which he then raised to specific rank of *S. streptodactylus.* We accept De Man's differentiation between the two species and discuss the criteria for the separation under *S. streptodactylus;* the erection of a new species, *S. metaneomeris streptodactylus,* by Coutière in 1921 is also discussed there.

Through the kindness of Dr Pinkster of the Zoölogisch Museum, Amsterdam, we were able to examine the two specimens De Man had studied from the Mergui Archipelago; both were female. These carried the label *A. minor neptunus,* evidently applied by De Man prior to his 1888 publication. These were part of the syntypic series in 1897 when he established *A. neomeris* and, on Dr Pinkster's recommendation, we designate one of these specimens as a lectotype (Museum number: ZMA De. 102.333).

We found De Man's description to be correct and adequate; we append drawings of the anterior region and of the dactyli of the third and fourth legs from the lectotype and paratype to supplement the 1897 and 1911 drawings of De Man.

However, in 1905 Coutière described another new species *S. gravieri* based on fourteen specimens which he considered closely related to De Man's *S. neomeris,* basing his comparison upon De Man's 1897 description. For the separation of the two species, Coutière pointed out a difference in the anterior region of the carapace ("Les deux épines orbitaires sont fréquement plus divergentes que chez le *S. neomeris*") and a series of minor differences in length in the antennular and antennal peduncles, in the proportion of the small chela, and in the proportions of the third, fourth and fifth thoracic legs. He also emphasized differences in the ungui of the dactylus of the third leg, stating it was characterized ". . . surtout par la réduction de la griffe dorsale, très grêle, n'ayant guère que 1/6 de l'épaisseur et 1/3 de la longeur de la griffe principale."

Two of these criteria were dismissed by De Man in his review of the three species in 1911. He pointed out that the drawing of the third leg (1897: 61b) was of *S. streptodactylus;* this was evidently the figure Coutière used for comparison of the proportions of the third leg. De Man, in a series of measurements of his specimens, showed that the range in proportions of the small chela encompassed the differences dwelt upon by Coutière. However, De Man accepted

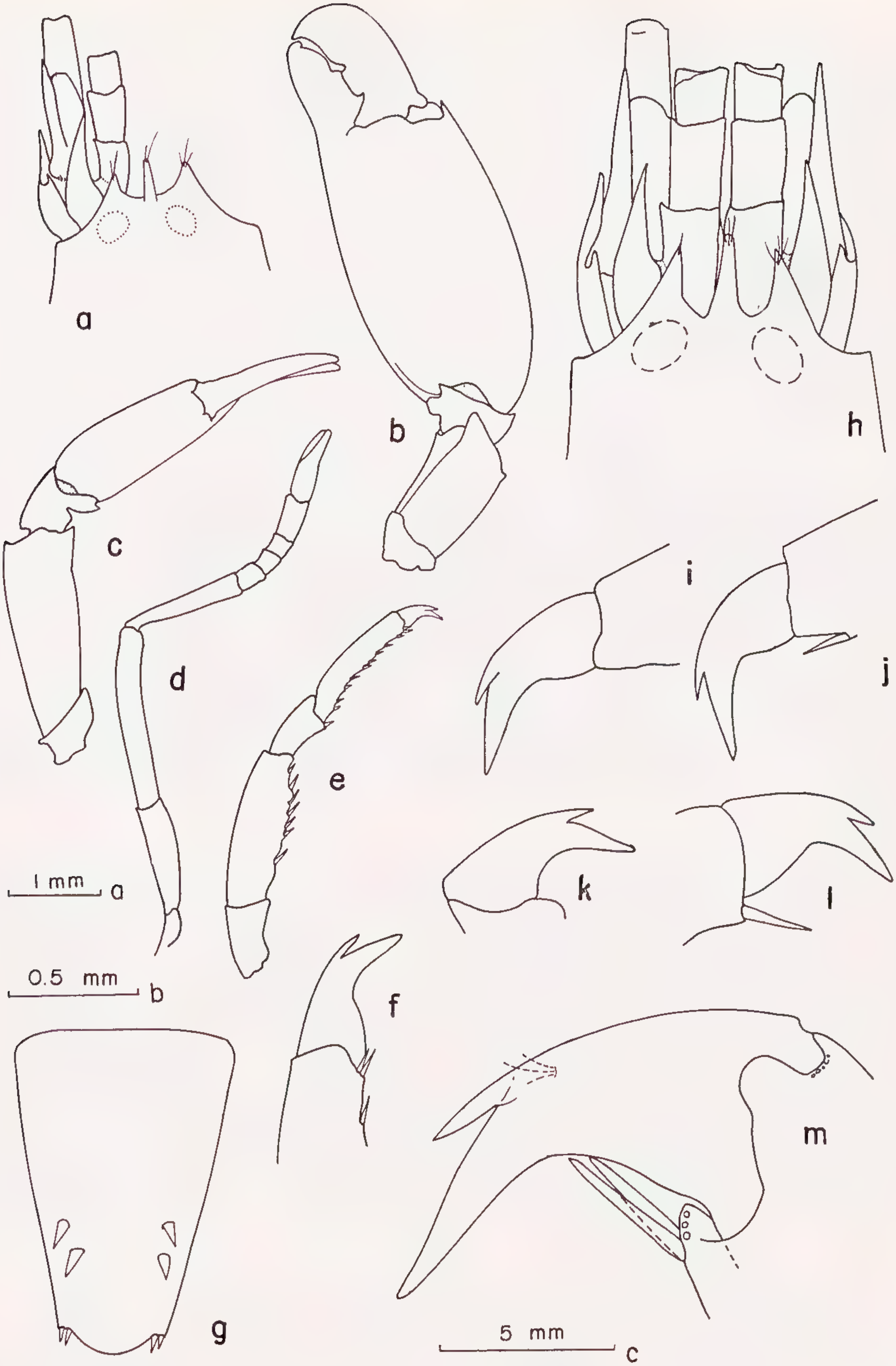


Fig. 22.—*Synalpheus neomeris* (De Man). Australian specimen, 28 mm male from AM 136: a, anterior region, dorsal view; b, large cheliped, outer face; c, small cheliped, superior face; d, second leg; e, f, third leg and dactyl; g, telson. Lectotype and paratype of *S. neomeris* (De Man) from the Mergui Archipelago: 18 mm female, lectotype; h, anterior region; i, j, dactylus of third and fourth legs. 17 mm female, paratype: k, l, dactylus of third and fourth legs. *S. gravieri* Coutière, holotype from Maldive Archipelago: m, dactylus of third leg drawn by J. Forest of the Nat. Mus. nat. Hist., Paris, g, h, scale a; f, i, j, k, l, scale b; a, b, c, d, e, scale c

the species and in the 44 specimens from the Siboga Station 258, placed nineteen specimens in *S. gravieri* and 25 in *S. neomeris*. He noted that the superior unguis reached one-third, not one-sixth the basal thickness of the major unguis.

We were given the opportunity to look at some specimens labelled by Coutière himself as *S. neomeris* and *S. gravieri* at the Muséum National d'Histoire Naturelle in Paris; we also examined at the Zoölogisch Museum in Amsterdam the specimens from Siboga Station 258 that De Man had identified. In none of these could we detect consistent differences. It is true that De Man's specimens of *S. gravieri* were smaller, the largest being 16 mm long, than the specimens of *S. neomeris,* with the largest 28 mm long. Most of the differences we saw appeared to be related to maturity.

From our Australian and other collections from the Pacific and Indian Oceans we have examined about eighty specimens. In this group we found the rostral front and the proportions of the antennular and antennal articles to be quite variable, as is often found in this genus, and that these variations encompassed the differences pointed out by Coutière. We ignored Coutière's supposed differences in the proportions of the third legs for if the comparison was made with De Man's 1897 figure 61b (the true *S. neomeris*) instead of 61d, no differences are apparent. We also paid no attention to the slight differences which ranged from 1–3 per cent in the ratio of lengths of merus, carpus and propodus of the fourth and fifth legs, for we have found that even if articles can be measured with such accuracy, the variation from left side to right side of one specimen may be greater than the percentage cited. The variation in this collection, then, destroyed all of the criteria for the separation of *S. gravieri* from *S. neomeris* except for the "très grêle" condition of the superior unguis of the third legs.

However, in none of our specimens did the superior unguis attain proportions set forth by Coutière. We found minor variations in the proportion and curvature, but these were interpreted to be within the range for *S. neomeris*. Our re-examination of specimens identified by both Coutière and De Man as *S. gravieri* showed that even these did not approach the proportions given by Coutière. We appealed to Dr Forest of the Muséum National d'Histoire Naturelle in Paris to re-examine Coutière's holotype for *S. gravieri*. He kindly did so, and forwarded to us a drawing of the unguis in question (fig. 22m). The drawing shows Coutière's type to have the superior unguis slightly more than one-third (0.36) the basal breadth, and slightly more than one-third the length (0.36), of the principal unguis. The proportions of the superior unguis thus falls within the range for *S. neomeris*. We therefore place *S. gravieri* as a junior synonym of *S. neomeris*.

To clarify previous records we find our two specimens reported from Thailand (1966b: 48) as *S. gravieri* to be also *S. neomeris*.

We were able to examine at the British Museum (Natural History) the specimen that Bate had identified in the Challenger Reports as *S. neptunus*; it was plainly *S. neomeris*. *S. prolificus* Ortmann (*nec* Bate) was placed in synonymy to *S. gravieri* by De Man (1911: 216) who was able to examine Ortmann's specimens from Kagoshima, Japan; thus it too should be recorded as *S. neomeris*.

Biological notes: This species has been collected commonly in association with alcyonarians. It has also been found associated with sponges. One specimen from Western Australia, collected in 23 fms, was reported to have been associated with a bryozoan. It has been collected from dead coral heads in fairly shallow water, and has been dredged as deep as 129 metres in Western Australia. Our specimens range in size from 12–25 mm.

The following colour notes were made by J. C. Yaldwyn on a pair of symbiotic specimens collected on the Swains Reefs (AM 163):

"To naked eye appears white, not transparent, with viscera very slightly pink. Through lens: Virtually no chromatophores on entire animal; nothing on bulk of carapace, abdomen, tail fan, anterior appendages, hands, legs, pleopods; eyes appear silver-grey through carapace; about four small and insignificant simple red chromatophores in approximate line between eyes; eggs completely colourless with dark eyes showing through."

Australian distribution: This species has been collected in Western Australia from Busselton to Cape Carnarvon and Houtman Abrolhos; in northern Australia at the Gulf of Carpentaria and the Torres Straits; in eastern Australia from Princess Charlotte Bay to Great Sandv Strait, south of Bundaberg, Queensland, and also from the Herald Group, Coral Sea.

General distribution (including reports for *S. gravieri*): Suez Canal; Red Sea; Persian Gulf; Ceylon; Maldive and Laccadive Archipelago; Singapore; Indonesia; Thailand; Shanghai; Japan and Sulu Sea*.

Synalpheus streptodactylus Coutière

Fig. 23

Synalpheus neomeris streptodactylus Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 870, fig. 1.

Alpheus neomeris De Man, 1897, Zool. Jb. Syst. 9: 734 [*partim*]. Coutière, 1905a. *op. cit.*: 869, fig. 1.

Synalpheus streptodactylus De Man, 1911, Siboga Exped. 39a[1] (2): 226, pl. 7, fig. 29.

Synalpheus metaneomeris streptodactylus Coutière, 1921, Trans. Linn. Soc. Lond. II, 17 (4): 414, pl. 60, fig. 4.

Synalpheus streptodactylus streptodactylus Banner & Banner, 1966a, Pacif. Sci. 20 (2): 157; 1966b, Siam Soc. Mono. 3, p. 50, fig. 14. Miya, 1972, Publ. Amakusa Mar. Biol. Lab 3 (1): 69, pl. 14.

Synalpheus streptodactylus hadrungus Banner & Banner 1966a, Pacif. Sci. 20 (2): 158.

Synalpheus jedanensis Barnard, 1950, Ann. S. Afr. Mus. 38: 738, fig. 139e–i [*nec* De Man]. Fourmanoir, 1958, Naturaliste malgache, 10 (1–2): 115, fig. 3 [*nec* De Man].

Additional Australian Records:

McNeil, 1968, Sci. Rept. Gt Barrier Reef Exped. 7 (1): 18. Lookout Point, N. E. Queensland.

Specimens examined: 2 specimens from AM 11; 6, AM 13; 1, AM 35; 3, AM 67; 1, AM 116; 9, AM 173; 1, AM 199; 6, AM 251; 1, AM 429; 1, AME 3180; 3, AME 4494; 4, AM E 4495; 7, AM E 4499; 2, AM E 6667; 1, AM P 8793; 2, AM P 10038; 5, AM P 13559; 1, AM P 13585; 1, BAU 14; 1, BAU 15; 1, BAU 17; 3, BAU 21; 75, BAU 25; 34, BAU 27; 20, BAU 28; 1, BAU 33; 3, BAU 40; 1, BAU 43; 4, BAU 44; 2, BAU 57; 1 specimen each from CS 13, 14, 18, 22; 1, UQ 14; 1, VM 32; 3, WM 24–65; 1, WM 29–65; 1, WM 34–65; 1, WM 38–65; 3, WM 94–65; 1, WM 107–65; 1, WM 182–65; 1, WM 250–65; 16, WM 268–65; 1, WM 288–65; 1, WM 290–65.

Diagnosis: Rostrum three times as long as broad at base, reaching variously from the middle to the last quarter of the visible part of the first antennular article. Orbital teeth broader at base and a little shorter than rostrum. Rostral base with orbitorostral process.

Visible part of first antennular article at least 1.5 times as long as second antennular article, third article a little shorter. Stylocerite reaching to middle of second antennular article. Scaphocerite with lateral tooth reaching well past antennular peduncle and almost as long as carpocerite. Squamous portion reaching near end of antennular peduncle. Inferior tooth of basicerite almost as long as stylocerite, superior tooth well developed and acute.

Large chela 2.7 times as long as broad, with fingers occupying slightly more than distal quarter. Superior margin of palm bearing acute tooth proximal to dactylus. Merus two times as long as broad with superior margin projecting as an acute tooth. Small chela 3.2 times as long as broad with fingers 0.8 length of palm. Merus similar in form to that of large cheliped.

Carpal articles of the second leg with a ratio: 10:1:1:1:3.

Merus of third leg varying from 3.8–4.4 times as long as broad, with inferior margin bearing 2–5 spines centred beyond middle, but none terminally. Carpus terminating in rounded superior tooth and two inferior spines. Propodus 6.2 times as long as wide, slightly curved, and bearing eight spines on inferior margin and two terminally. Dactylus biunguiculate, 0.2 as long as propodus and strongly hooked; superior unguis 0.3–0.5 as thick, and 0.5 to almost 1.0 as long as inferior unguis. Merus of fourth leg usually bearing one or two spinules; merus of fifth leg unarmed.

Telson 2.8 times as long as posterior margin is wide. Lateral distal corners extended into small but acute teeth. Anterior pair of dorsal spines sometimes slightly posterior, but more often slightly anterior to middle.

Discussion: As discussed under *S. neomeris*, specimens of this species were confused by De Man with those of *S. neomeris* when he described that species originally in 1897. Coutière (1905a) separated the two forms, creating *S. neomeris streptodactylus*. De Man (1911) accepted the separation, but raised the subspecies to specific rank. An examination of 138 specimens from Australia and 58 specimens from the Philippines as well as specimens of *S. neomeris* already cited, allows us to agree with Coutière and De Man that the two species are closely related but specifically separate. Probably the most important characteristic lies in the dactyli of the third legs as mentioned by previous authors. In *S. streptodactylus* the superior unguis is half or more than half as long as the inferior, and usually half as thick at its base; in *S. neomeris* the superior unguis is about one-third as long (rarely reaching half as long) and one-third as thick at its base. We also have discovered several other characteristics useful for separation: In both species the carpocerite is much longer than the antennular peduncles, but in *S. streptodactylus* the lateral tooth of the scaphocerite is nearly equal in length to the carpocerite, while in *S. neomeris* it is equal to the antennular peduncles. In *S. streptodactylus* the posterolateral angles on the telson project as small acute teeth, and the anterior pair of dorsal spinules are wide apart and located near the middle of the anterior-posterior axis; in *S. neomeris* the posterolateral angles are not projecting and the anterior pair of dorsal spinules are close together and posterior to the middle (compare fig. 22g with 23g). Finally there may be an ecological difference, for the only noted symbiotic relationship of *S. streptodactylus* has been with sponges, while *S. neomeris* came from alcyonarians and bryozoans as well as sponges.

Both Barnard (1950: 738) and Fourmanoir (1958: 115) have pictured the dactylus of the third legs of specimens they have named *S. jedanensis*. When they are compared to De Man's original figure for that species (1911, fig. 27c) and to this species, one is convinced that the African specimens are actually *S. streptodactylus*. Further supporting this contention is that these specimens came from sponges, a common habitat for *S. streptodactylus*.

The separation of the species into two subspecies is questionable. As we discussed before (1966a: 157) it is not clear whether the intent of Coutière when he applied the name *S. metaneomeris streptodactylus* in 1921 (p. 414) was to merely rename an existing species, plainly in conflict with rules of nomenclature, or to create a new subspecies on the basis of the subtle differences between the ungui of the dactyls of the third legs. In 1966a we presumed the latter and named the nominate species *S. streptodactylus streptodactylus* and the form with the heavier ventral unguis *S. streptodactylus hadrungus* (=*S. metaneomeris streptodactylus* Coutière). We found that all of our central Pacific specimens were *S. s. streptodactylus*. Since then we have examined six specimens from the collections of the Muséum National d'Histoire Naturelle in Paris that had been identified by Coutière as *S. streptodactylus*, and we found their ungui to be variable. This point, together with the variation found in this extensive collection, has convinced us that the separation between the subspecies is invalid and that only the nominate species should be recognized.

Biological notes: This is not a large species. Our mature specimens range in length from 10–15 mm with the exception of eighteen specimens from South Australia and one from Frèmantle which are 20 mm in length. The species has been found from intertidal zone to as deep as 70 fathoms.

While it has been reported from heads of "dead coral" it is often found in large numbers in the spongocoel of various sponges. We suggest that perhaps it is almost always associated with sponges. Those reported from "dead coral" may have been actually living in sponges that so often invade dead portions of coral, and fell out, not of the coral, but of the sponges, when the coral was broken apart. Those reported as taken from "the growth on a pearl oyster shell" could also have come from sponges growing on the shell.

The only colour notes on this species are ours: We found three salmon pink specimens from an orange-red membranous sponge in Western Australia (BAU 4), however, specimens from the brownish sponge *Zygomycale parishii* (Bowerbank) in Hawaii are of a brown colour similar to the sponge.

Australian distribution: This species has been found on all the coasts of Australia.

General distribution: Red Sea, Ghardaqa, South Africa, Maldive and Laccadive Archipelagoes, Sumatra, Thailand, Philippines*, Japan, Tonga, Samoa, Canton Islands, Hawaii.

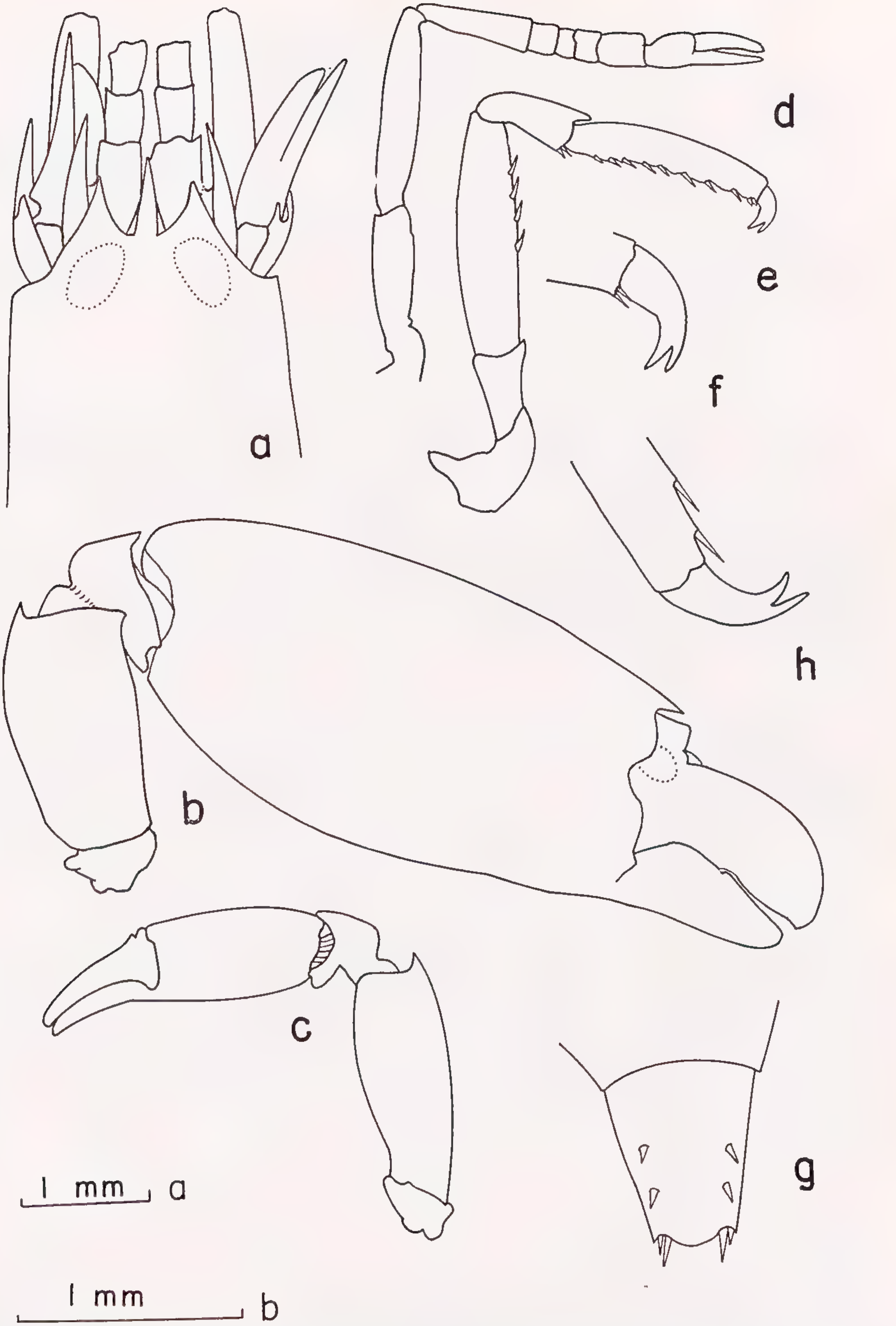


Fig. 23.—*Synalpheus streptodactylus* Coutière. 15 mm male from BAU 38: a, Anterior region; b, large cheliped; c, small cheliped; d, second leg; e, f, third leg and dactylus; g, telson. 17 mm female from WM 288-65: h, dactylus of third leg. a, b, c, d, e, g, scale a; f, h, scale b.

Synalpheus pococki Coutière

Fig. 24 a–h

Synalpheus neomeris var. *pococki* Coutière, 1898d, Bull. Soc. Ent. France 1898 (7): 167, fig. 2 [Holothuria Bank, N. W. Australia, Macclesfield Bank, Arafura Sea].

Synalpheus pococki De Man, 1911, Siboga Exped. 39a[1] (2): 234, fig. 32.

Additional Australian Records:

Coutière, 1900, Bull. Mus. Hist. nat., Paris 6 (8): 411, Albany Passage, Torres Straits.

Specimens examined: 1, 19 mm female from AM 67 (near Darwin).

Diagnosis: Rostrum slender, 3.5 times as long as broad at base, reaching to end of first antennular article. Orbital teeth a little shorter with outer margins straight, inner margins concave. Rostral base with orbitorostral process.

Visible part of first antennular article a little longer than second; third a little shorter than second. Stylocerite reaching middle of second antennular article. Squamous portion of scaphocerite not reduced, reaching near end of antennular peduncle; lateral tooth longer than peduncle. Carpocerite 4.0 times as long as broad when viewed from below, slightly longer than antennular peduncle. Inferior spine of basicerite a little shorter than stylocerite, superior spine prominent, acute.

Large chela 2.6 times as long as broad, fingers occupying almost the distal one-third, with acute tooth above dactylar articulation. Merus three times as long as broad, superodistal margin terminating in an acute tooth, inferior margins inermis. Small chela 4.0 times as long as broad, fingers 0.38 the total length. Carpus 0.6 as long as broad, with superodistal margins armed with acute tooth.

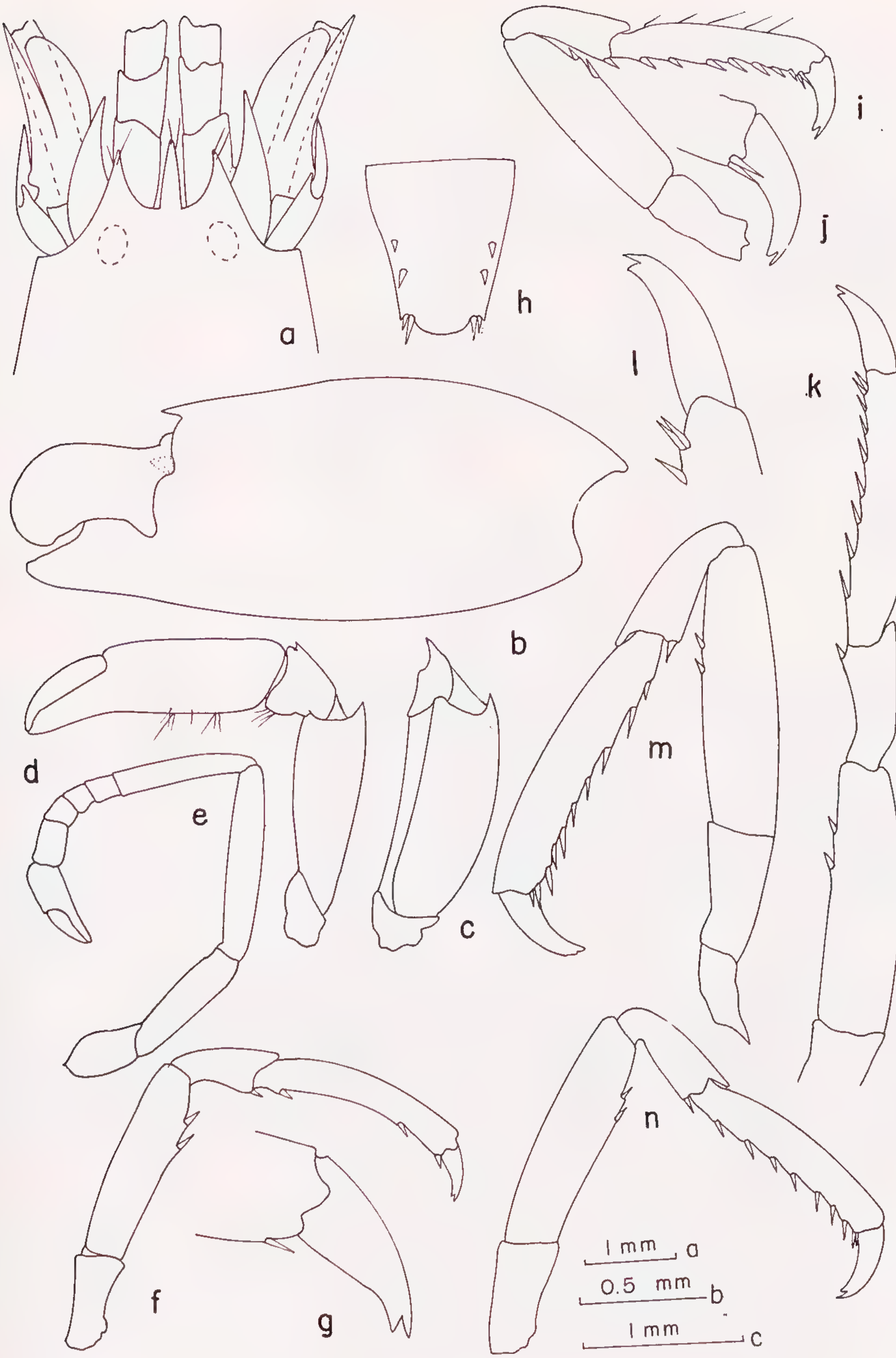
Carpal articles of the second leg with a ratio: 10:1:1:1:3; third article about as long as broad.

Merus of third leg four times as long as broad, bearing two short strong spines on distal half, but distal margins unarmed. Carpus 0.4 as long as merus, distosuperior margin terminating in obtuse projection, distoinferior margin with spine. Propodus distinctly curved, bearing one spine proximally and one at about three-quarters length along inferior margin; one distal spine. Dactylus one-fourth as long as propodus, unguis about one-eighth as long as entire dactyl; inferior unguis thicker at base and a little shorter than superior unguis.

Telson 2 times as long as wide, posterolateral angles slightly projecting and acute.

OPPOSITE

Fig. 24.—*Synalpheus pococki* Coutière and *Synalpheus iocosta* De Man. *Synalpheus pococki*: 11 mm male from AM 67; a, Anterior region, dorsal view; b, c, large chela and merus, inner face; d, small cheliped; e, second leg; f, g, third leg and enlarged dactylus; h, telson. *Synalpheus iocosta*, 14 mm male from AM 13: i, j, third leg and dactylus. 13 mm female from WM 94–65: k, 1, third leg and dactylus. 13 mm female from WM 290–65: m, third leg. Superior unguis. In reduction the roughness where the unguis was attached no longer may be seen. 12 mm female from WM 69-65: n, third leg. a, b, c, d, e, f, h, scale a; g, j, l, scale b; i, k, m, n, scale c.


a
b
c
d
e
f
g
h
i
j
k
l
m
n
1 mm a
0.5 mm b
1 mm c

Discussion: The only difference between this species and *S. iocosta* De Man is the nature of the third leg (*see below*). Our specimen agrees well with Coutière's original description as well as De Man's specimen from Indonesia.

Biological notes: Our specimen was taken from a "growth on a pearl shell", and that of De Man's was captured in a dredge at 13 metres. Coutière did not make any remarks about possible habitats of his specimens, but his specimens from Albany Passage were dredged at 10 fathoms. We suggest that the unique propodus of this species may be an adaptation for a special environment, similar to the hooked dactylus of the small chela of *S. comatularum,* and the strange ungui of the third legs of *S. charon*; however, no available data suggests what this habitat might be.

Australian distribution: Darwin, Arafura Sea and Torres Straits.

General distribution: De Man's specimen from the east coast of Aru Islands in Indonesia is the only record from other than Australia.

Synalpheus iocosta

De Man

Fig. 24 i–n

Synalpheus iocosta De Man, 1909a, Tijdschr. ned. dierk. Vereen. II, 11 (2): 119; 1911 Siboga Exped. 39a[1] (2): 235, fig. 33.

Specimens examined: 1 specimen from AM 13; 1 specimen each from CS 19, 20, 21; 1, WM 69–65; 1, WM 94–65; 1, WM 290–65.

Discussion: As this species is almost exactly the same as *S. pococki* Coutière (p. 366) except in the propodus of the third leg we are not offering a separate description. In the propodi, that of *S. pococki* is distinctly curved, more curved than any other synalpheid, and bears but three spines while in this species it is almost straight and bears 7–8 spines along the inferior margin. We have pictured the legs from four specimens and show how consistent they are in proportion and armature. De Man in his original description of this species, with a series of 42 specimens, points out that the dactylus of the third leg is longer, less heavy and has smaller ungui than in *S. pococki,* but that these characteristics are variable. Our specimens of the two species are in excellent agreement with the original descriptions. One might question the separation of the two species, but certainly nothing in the present collections nor from those previously reported would indicate that the separation of the species is other than valid.

Biological notes: This species has only been collected in dredges from many types of bottoms in water up to 72 fathoms. The three specimens dredged from Cockburn Sound were found associated with sponges and bryozoans. Our specimens ranged from 9–12 mm in length.

Australian distribution: From Cape Naturaliste to Carnarvon in Western Australia and one specimen from the Gulf of Carpentaria.

General distribution: This species has not been reported since De Man's original specimens from the Aru Islands.

Synalpheus charon (Heller)

Fig. 25

Alpheus charon Heller, 1861, Sbr. Akad. Wiss. Wien 44 (1): 272, pl. 3, fig. 21, 22; 1865, Reise Novara Crust. 2 (3): 107. Paulson, 1874, Invest. Red Sea Crust., 1: 104, pl. 8, fig. 4.

Synalpheus charon De Man, 1911. Siboga Exped. 39a[1] (2): 245, figs. 37. Banner, 1953, Pacif. Sci. 7 (1): 37, fig. 11. Banner & Banner, 1967, Bishop Mus. Occ. Pap. 23 (12): 262.

Synalpheus charon charon Banner, 1956, Pacif. Sci. 10 (3): 331.

Synalpheus charon obscurus Banner, 1956, Pacif. Sci. 10 (3): 329, fig. 5.

Synalpheus prolificus Bate, 1888, Challenger Rept. 24: 556, pl. 99, fig. 4.

Synalpheus helleri De Man, 1911, Siboga Exped. 39a[1] (2): 245, fig. 37.

Additional Australia Records: Patton, 1966, Crustaceana 10 (3): 281, 289. Willis, I., Coral Sea and Wistari Reef, Queensland.

Specimens examined: 1 specimen from AM 123; 1, BAU 33.

Diagnosis: Rostrum with margins of proximal section usually parallel, distal section forming an acute triangle, not reaching to end of visible part of first antennular article. Orbital teeth acute, a little shorter and much broader at base than rostrum. Rostral base with orbitorostral process.

Antennular peduncles stout, articles subequal. Stylocerite reaching slightly past middle of second antennular article. Squamous portion of scaphocerite reaching end of antennular peduncle, lateral spine longer, reaching to end of carpocerite which is at least half the length of the third article past that article. Carpocerite 3.5 times as long as broad. Inferior spine of basicerite not quite as long as stylocerite, superior margin rounded.

Large chela 2.6 times as long as broad, fingers occupying the distal third; slight protrusion above dactylar articulation. Merus 2.3 times as long as broad; superodistal margin terminating in acute tooth, distal ends of inferior margins inermous. Small chela almost three times as long as wide, finger 0.4 of total length. Merus 2.3 times as long as broad, superodistal margin terminating in small acute tooth.

Carpal articles of the second leg with a ratio 10:1.7:1.7:1.7:5. First article as long as four following; second to fourth article broader than long.

Merus of third leg inermis, three times as long as broad, carpus 0.4 as long as merus with superior margin projecting as tooth, inferior bearing heavy spine. Propodus 0.8 as long as merus, bearing on its inferior margin 3–4 short heavy spines, with a pair distally. Dactylus stout, ungui about a third of total length. Inferior unguis obtuse, only slightly curved, inferior surface with excavate "pocket". Superior unguis thin and composed of an acute tip and a lateral flange. (*See* Banner, 1956, fig. 5.)

Telson as usual for *Synalpheus*, 2.3 times as long as posterior margin is broad; distolateral margins not projecting, nor acute. Posterior margin arcuate. Anterior pair of dorsal spines located in the middle.

Discussion: This species is readily recognized by the dactyli of the thoracic legs which have the heavy inferior unguis with the pocket-like cavity in the lower side and the smaller acute upper unguis with the lateral flange. No other species of the genus *Synalpheus* bears a similar dactylus.

The great variation in the rostral front has lead to the separation of one new species and one new subspecies, *S. helleri* De Man and *S. charon obscurus* Banner. We placed these in synonymy in 1967 (Banner & Banner, 1967: 262). We have figured the rostral front of both of our specimens because they show the range of variation (figs 25 a and h). The rostrum in the specimen from AM 123 is of the type with the straight proximal portion which was considered as characteristic of *S. helleri* and *S. charon obscurus.* The rostrum of the specimen from BAU 33 is the more typical.

The review of the Hawaiian alpheids (Banner, 1953) discussed *S. prolificus* (Bate), known only from a single specimen from "Off Honolulu, Sandwich Islands". We suggested that if the ungui of the third legs were similar to *S. charon,* then the two species were closely related. However, we remarked that "the nature of the second legs and of the stylocerite would be valid characteristics for the separation of the two species". The British Museum (Natural History) afforded us the opportunity to re-examine the type specimen of Bate's species. None of the supposed differences between *S. prolificus* and *S. charon* are valid. The rostrum is of the type with parallel sides proximally; the stylocerite reaches the middle of the second antennular article; the first carpal article of the second legs is only slightly longer than the sum of the four following, therefore within the range of variation; and, most important, the ungui of the dactyli of the third legs have development characteristic of *S. charon. S. prolificus*, a species unreported since it was described in 1888, is plainly a synonym of *S. charon.* We have added figures of Bates's holotype to our figures of Australian specimens.

Biological notes: This species appears to live largely, if not entirely, on living coral. It has been commonly collected from heads of *Pocillopora meandrina* Verrill in association with *Alpheus lottini* Guérin, and crabs of the genus *Trapezia* (Banner, 1953: 38). All three crustaceans are orange-red in colour. In Australia it has also been found in *Stylophora pistillata* (Esper) and *Seriatopora* sp. (Patton, 1966). The specimen from BAU 33 was taken from a living *Porites* sp. In non-Australian waters, it has been collected from dead coral heads in shallow water and Bate's specimen was dredged from 33 metres. The Australian specimens are small, 10–13 mm in length, but it has been reported up to 22 mm in length.

Australian distribution: Heron Island and Wistari Reef in the Capricorn Group, Rudder Reef, off Port Douglas, and Willis I., Coral Sea.

General distribution: This species has been reported from the Red Sea to Mexico, and from Japan to the Great Barrier Reef. We have seen specimens in the American Museum of Natural History in New York from Ecuador and Columbia, South America.

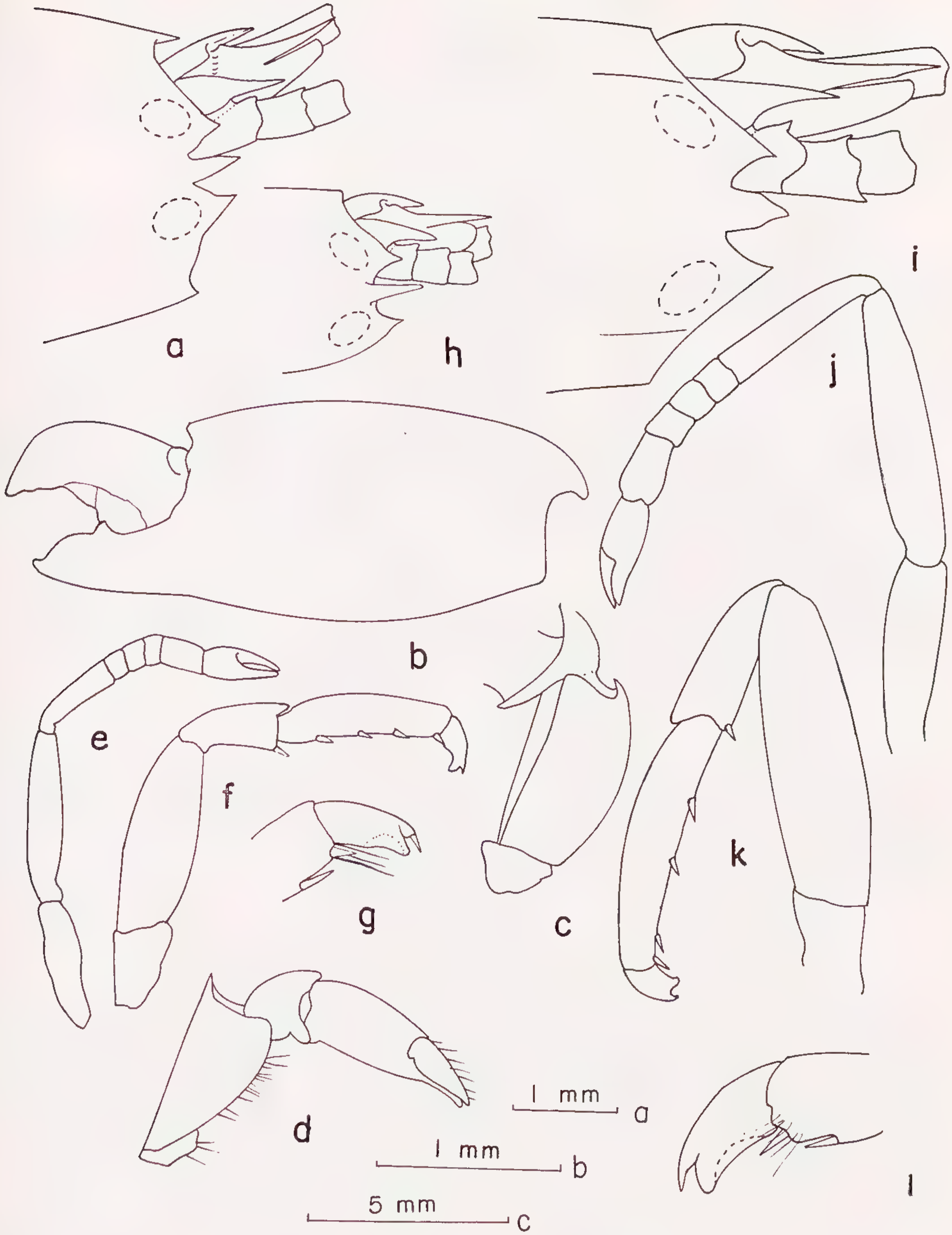


Fig. 25.—*Synalpheus charon* (Heller). 13 mm female from AM 123: a, anterior region, dorsal view; b, c, large chela and merus; d, small cheliped; e, second leg; f, g, third leg and dactylus. 10 mm female from BAU 33: h, anterior region, dorsal view. *Alpheus* (*Synalpheus*) *prolificus* Bate, from "Off Honolulu". Holotype: i, anterior region, dorsal view; j, second leg; k, l, third leg and dactylus. a, b, c, d, e, f, h, j, k, scale a; g, l, scale b; i, scale c.

Synalpheus gracilirostris De Man

Fig. 26

Synalpheus gracilirostris De Man, 1910b. Tijdschr. ned. dierk. Vereen: 11 (4): 291; 1911, Siboga Exped. 39a[1] (2): 269, fig. 49.

Specimens examined: 1, 11 mm male from BAU 44.

Diagnosis: Rostrum awl-shaped, reaching to middle of second antennular article. Orbital teeth narrow and acute, reaching to middle of visible part of first antennular article. Rostral base with orbitorostral process.

Visible part of first antennular article 1.5 times longer than second, second and third articles equal. Second antennular article as broad as long. Stylocerite reaching to last quarter of second antennular article. Squamous portion of scaphocerite narrow, reaching to end of third antennular article, lateral spine much longer reaching about length of third article past that article. Carpocerite 4.0 times as long as broad, reaching about half way from end of third article to end of squame. Basicerite with inferior spine as long as stylocerite, superior spine acute and prominent.

Large chela 2.8 times as long as wide with fingers one-third total length, with acute tooth above dactylar articulation. Merus 2.7 times as long as broad, superior margin terminating in an acute tooth, other margins inermous. Small chela three times as long as broad, fingers shorter than palm. Carpus cup-shaped, 0.2 as long as chela, merus similar to that of large chela.

Carpal articles of second leg with a ratio: 10:1:1:1:5.

Merus of third leg five times as long as broad. Carpus 0.5 as long as merus, with superior margin terminating in an obtuse tooth, inferior margin terminating in a heavy spine. Propodus as long as merus and bearing on inferior margin seven spines and a pair distally. Dactylus biunguiculate, superior unguis a little longer but equal in thickness at base to inferior unguis.

Telson 2.6 times as long as posterior margin is broad. Posterolateral angles slightly projecting and acute, about half as long as outer posterior spine.

Discussion: De Man based his description on two specimens. We have one specimen from Australia and two from Zamboanga, Philippines; the species has not otherwise been reported. Our three specimens are similar to each other, and differ from De Man's description in four ways: 1) the inferior spine of the basicerite is almost equal in length to the stylocerite instead of "much shorter than the stylocerite". 2) The superior spine of the basicerite of our specimen is prominent and acute while De Man states "upper angle subacute, but not spiniform". 3) The anterior margin of the chela terminates in an acute tooth rather than a "small, rather obtuse tubercle". 4) The lateral angles of the telson in our specimens are more produced.

All four characteristics are known to be somewhat variable in the genus, but in combination, especially with the marked difference in the inferior spine of the basicerite, they may indicate a new species. However, with a total of five specimens known and with variability so common among many species of synalpheids, we are deferring the application of a new name.

Biological notes: De Man's specimens were dredged from 54 metres, but our three specimens have come from dead coral in waters up to 2 metres deep. It is a small species with none of the known specimens longer than 11 mm.

Australian distribution: Our specimen came from Hayman Island in the Whitsunday Group, Queensland.

General distribution: Timor in Indonesia; southern Philippines.*

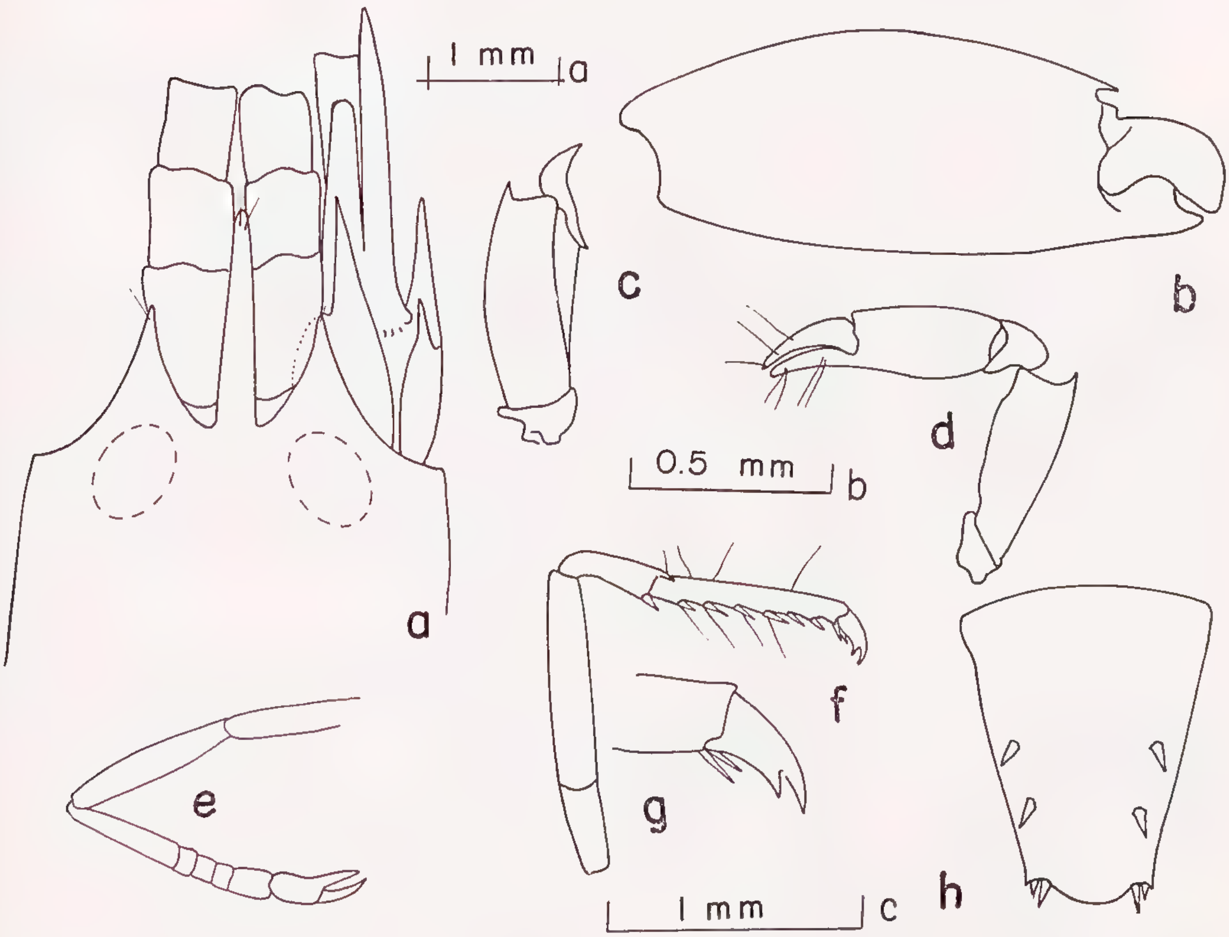


Fig. 26.—*Synalpheus gracilirostris* De Man. 11 mm male from BAU 44: a, anterior region, dorsal view; b, c, large chela and merus; d, small cheliped; e, second leg; f, g, third leg and enlargement of dactylus; h, telson. b, c, d, e, f, scale a; g, scale b; a, h, scale c.

Synalpheus echinus sp. nov.

Fig. 27

Holotype: 17 mm female from Trigg Island, near Perth, Western Australia, collected by W. H. Butler, 20/14/61 (WM 92–65).

Paratypes: 1, 14 mm incomplete female from same location as type; 1, 28 mm ovigerous female from Carnac Is. collected by E. P. Hodgkin (WM 51–65); 1, 17 mm male and 1 large mutilated female from Rottnest Is. (WM 12822/12823); 3 males and 3 females, 16–20 mm from Lancelin Is., (BAU 3 and BAU 4). All localities are near Perth, Western Australia.

Diagnosis: Rostrum narrow almost 3 times as long as broad at base, reaching to end of first antennular article. Orbital teeth also slender, but slightly more than half as long as rostrum; teeth divergent. Rostral base with orbitorostral process.

Visible part of first antennular article 1.7 times as long as second article; second and third article of same length. Stylocerite reaching to near middle of second antennular article. Squamous portion of scaphocerite narrow, as long as antennular peduncle, outer spine longer than carpocerite. Carpocerite subequal to antennular peduncle, 4.0 times as long as broad. Inferior spine of basicerite as long as stylocerite, superior spine reaching to level of tips of orbital teeth.

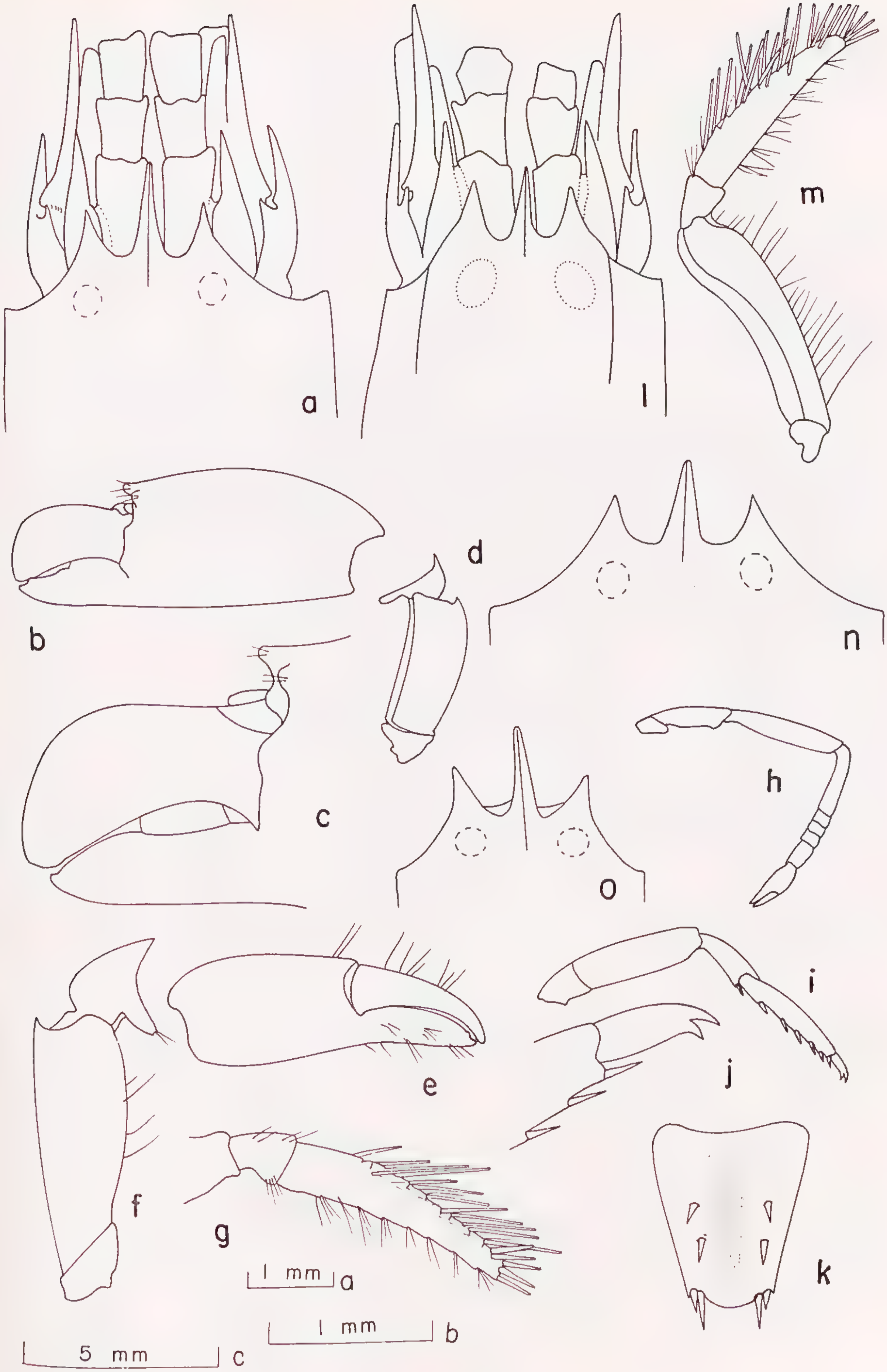
Distal article of third maxilliped bearing on distal two-thirds of superomedial face an armature of 10–20 strong but elongate spines with blunt or acute tips (the spines with blunt tips may represent longer spines that have been broken). Tip of article carrying a circlet of five spines, shorter and heavier than those of face.

Large chela stout, 2.8 times as long as broad, fingers occupying the distal third. Margin of palm above dactylar articulation terminating in two rounded projections, the superior larger. Merus 2.6 times as long as broad, fingers a little shorter than palm; fingers with random setae only; tips of both dactyl and pollex bearing two low cusps. Merus 2.7 times as long as broad, distosuperior margin bearing triangular tooth.

Carpal article of second leg with a ratio: 10:2.0:1.5:1.5:4.0, middle articles broader than long.

OPPOSITE

Fig. 27.—*Synalpheus echinus* sp. nov. Holotype, 17 mm female from WM 92-65: a, anterior region, dorsal view; b, c, large chela and enlargement of distal section; d, merus large chela; e, f, small chela, merus and carpus; g, distal article of third maxilliped of holotype, lateral view (setae on medial face omitted); h, second leg; i, j, third leg and enlargement of dactyl; k, telson. Paratype, 17 mm male from BAU 44: l, anterior region, dorsal view; m, third maxilliped of specimen from BAU 4 (setae on medial face omitted). Paratype, 27 mm female from WM 51-56: n, anterior region, dorsal view. 14 mm female from BAU 4: o, anterior region of carapace, dorsal view. a, e, f, g, h, l, m, n, o, scale a; c, j, scale b; b, d, h, i, scale c.


a
l
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1 mm a
1 mm b
5 mm c

Merus of third leg 3.7 times as long as broad, inermous. Carpus 0.4 as long as merus, superodistal margin extending as obtuse tooth, inferodistal margin terminating in strong spine. Propodus subequal in length to merus, bearing on its inferior margin five strong spines and a pair distally. Dactylus biunguiculate, ungui equally thick at bases, but with superior unguis a little longer than inferior. Apex between ungui "V"-shaped.

Telson 1.6 times as long as posterior margin is broad; posterolateral angles acute and projecting, but much shorter than adjacent spine. Dorsal surface of telson slightly concave along midline.

Discussion: If Coutière's groups are to be used, this species would probably best be placed in the Paulsoni Group.

As far as we can determine this species differs from all other species of *Synalpheus* in the armature of the third maxilliped. While most synalpheids have spines on the tip of the maxillipeds, they have short bristles or long hairs on the inner face, but this species has spines also on the inner face. Unfortunately, the maxillipeds are usually not mentioned in specific descriptions, so we cannot state conclusively that this is a unique characteristic in the genus. Certainly no condition like this was reported by Coutière in his thesis (1899: 171) or in any species description that we have seen: moreover, we have examined all those species in our collections and in the collections of the Smithsonian Institution and found no parallel development. The species has two other characteristics which, while not unique, are rare enough to be noteworthy: the narrowness of the rostrum, and the shortness of the carpocerite. The plate illustrates some of the differences we have noted in the development of the rostral front.

The specific name is from the Greek *echinos* and refers to the spines on the maxillipeds. The holotype and four paratypes will be deposited at the Western Australian Museum. Six paratypes will be placed at the Australian Museum.

Biological notes: There are no notes in the collection which indicate any unique habitat; all came from coral heads from 3 metres or less deep; the specimen from Carnac Island came from "reef platform". The specimens range from 17–28 mm.

Australian distribution: All specimens in the collection came from near Perth, Western Australia.

Synalpheus tumidomanus (Paulson)

Fig. 28

Alpheus tumidomanus Paulson, 1875, Invest. Crust. Red Sea (1): 101, pl. 13, fig. 2.

Synalpheus tumidomanus Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 876, pl. 73, fig. 14; 1909, Proc. U.S. natn. Mus. 36: 24, fig. 5. Banner & Banner, 1968, Micronesica 4 (2): 275.

Synalpheus tumidomanus exilimanus Coutière, 1909, Proc. U.S. natn. Mus. 36: 10 [note: the combination was proposed by Coutière without explanation, and the name "*exilimanus* Paulson" evidently was substituted in error for Paulson's *gracilimanus*, 1875: 102].

Synalpheus hululensis Coutière, 1908a. Bull. Soc. Philomath., Paris 11 (5): 202.

Synalpheus hululensis hululensis Crosnier & Forest, 1966, Rés. Sci. Camp. Calypso 27 (19): 297, fig. 30.

Synalpheus mac-cullochi Coutière, 1908a, Bull. Soc. Philomath., Paris IX, 11 (5): 203. Hale, 1927b, Trans. R. Soc. S. Aust. 51: 308.

Synalpheus theophane De Man, 1911, Siboga Exped. 39a[1] (2): 261, pl. 10, fig. 44.

Synalpheus anisocheir Stebbing, 1915, Ann. S. Afr. Mus. 15: 86, pl. 23. Barnard, 1950, Ann. S. Afr. Mus. 38: 736, figs 139 a–d.

Synalpheus japonicus Yokoya, 1936, Jap. J. Zool. 7: 133, fig. 3.

Nec. Synalpheus tumidomanus Kubo, 1940a, J. Imp. Fish. Inst., Tokyo 34 (1): 90, text fig. 11, 12 (= *S. hastilicrassus* Coutière).

Nec Synalpheus anisocheir Fourmanoir, 1958, Naturaliste malgache 10 (1–2): 116, fig. 4 (identity unknown).

Additional Australian Records: McNeill, 1968, Gt Barrier Reef Exped. Sci. Rep. 7 (1): 17. Low Isles.

Specimens examined: 3 specimens from AC 29; 1, AC 30; 2, AC 35; 4, AM 1; 1, AM 16; 1, AM, 31; 4, AM 35; 1, AM 60; 1, AM 65; 7, AM 75; 1, AM 101; 2, AM 115; 6, AM 122; 1, AM 131; 2, AM 158; 2, AM 187; 4, AM 189; 2, AM 210; 2, AM 220; 2, AM 251; 1, AM 253; 1, AM 255; 1, AM 256; 1, AM 264; 2, AM 273; 1, AM 305; 2, AM 396; 1, AME 4495; 14, AM P 858; 2, AM P 2149; 1, AM P 3956; 2, AM P 4837; 1, AM P 4863; 2, AM P 5491; 1, AM P 6308; 1, AM P 6353; 1, AM P 6488; 3, AM P 6527; 1, AM P 6825; 6, AM P 8266; 2, AM P 8701; 2, AM P 8970; 1, AM P 9072; 2, AM P 11187; 1, AM P 11272; 3, AM P 13562; 3, AM P 13565; 3, AM P 13582; 6, SMC 805; 17, VM 33; 17, VM 35; 1, WM 47–65; 1, WM 52–65; 3, 76–65; 3, WM 99–65; 2, WM 105–65; 3, WM 112–65; 2, WM 117–65; 1, WM 125–65; 4, WM 141–65; 1, WM 155–65; 3, WM 164–65; 11, WM 175–65; 2, WM 177–65; 8, WM 181–65; 2, WM 240–65; 4, WM 268–65; 3, WM 297–65; 1, WM 173–60.

Table 5. Variations in Synalpheus tumidomanus (*Paulson*)

Characteristic	*S. tumidomanus* (from Paulson's description and figures)	9 specimens from Torres Straits, BAU 27	27 specimens from around Australia
Length, rostrum to antennular articles	Approaching end of first	Three-fourths first to one-fourth second.	From one-half first to one-quarter second.
Length, orbital teeth to rostrum	0·7 length, (from plate)	From 0·5 to 0·8 length.	From 0·5 to 0·9 length.
Length, stylocerite to antennular articles	Middle of second	Middle to near end of second.	Middle to near end of second.
Length, squame to antennular articles	End of second (from plate)	Base to three-fourths length of third.	Base to end of third.
Length, lateral spine of scaphocerite to antennular articles.	End of third	Slightly shorter to slightly longer than third.	Slightly shorter to slightly longer than third.
Length, carpocerite to antennular articles	End of third	Surpasses by one-fourth to one-half length of third.	Surpasses by entire length of third.
Length/breadth ratio of carpocerite (viewed laterally).	5·2 (from plate)	4·5–6·0.	4·0–6·0.
Length, inferior tooth basicerite to antennular articles.	(Not clear from plate)	Three-fourths length to end first.	From three-fourths length first to middle second.
Superior tooth, basicerite	Short, acute	Acute angle, slightly projecting.	From rounded to projecting acute tooth.
Length/breadth ratio of large chela	2·7 (from plate)	2·5–2·8.	2·3–3·0.
Nature of protrusion above dactylus, large chela.	Strong, rounded	From no protrusion to acute tooth.	From no protrusion to acute tooth.
Length/breadth ratio of small chela	Not given	3·0–3·4.	2·7–3·4.
Second leg carpus, ratio of first article to 4 following.	First longer than sum of four following.	First article from slightly shorter to slightly longer than sum of four following.	First article from slightly shorter to slightly longer than sum of four following.
Length/breadth ratio of merus of third leg.	Not stated	4·0–4·8.	3·5–5·0.
Posterolateral angles of telson	Angular teeth half length of adjacent spines.	Acute angle only slightly projecting.	From almost a right angle to acute projecting teeth.

Diagnosis: Table V sets forth the major diagnostic characters of *S. tumidomanus* with three exceptions: 1. The rostral base has an orbitorostral process. 2. The meri of the large and small chela are characterized by an acute tooth on the distosuperior margin. 3. The biunguiculate dactyli of the third legs have the superior unguis a little longer and thicker at the base than the inferior, and the notch between the ungui is "V"-shaped, almost acute.

Discussion: The long and rather confused application of names to specimens of this species or species complex had been discussed originally by Coutière in several papers (1899, 1905, 1909), reviewed by De Man (1911), Holthuis (1952), Crosnier and Forest (1966), Banner & Banner (1968) and Miya (1972). The problem appears to resolve itself at this time to the consideration of the appropriate name for, and extent of variation in populations of, three possibly separate species found in three separate faunal realms: The Indo-Pacific, the tropical eastern Atlantic, and the tropical and subtropical eastern Pacific. Holthuis has discussed the eastern Pacific form and has applied the name *S. spinifrons* (H. Milne-Edwards) to the species that Coutière had once lumped under the name *S. tumidomanus* and later named *S. latastei*. Holthuis did not discuss *S. lockingtoni* which may be related. Crosnier and Forest, considering the tropical Atlantic specimens, established two subspecies of *S. hululensis* Coutière and established a lectotype for the parent species from Coutière's Maldive and Laccadive specimens. We, working with twenty-two specimens from the Marshall Islands and other central Pacific collections, pointed out the wide range of variation in characteristics previously considered to be of worth for specific identification and placed *S. hululensis* and *S. theophane* De Man in synonymy under *S. tumidomanus* (Banner & Banner, 1968: 275).

Because of the difficulties that have been found in this group of nominal species, we have decided to use this large Australian collection to determine if our conclusions from the Marshall Islands were correct. We have augmented the study with a collection of twenty specimens from the Red Sea, Paulson's type locality. However, as we have no specimens from either the Atlantic or eastern Pacific, we do not extend our conclusions to the species complexes of these other realms.

In our 1968 paper, we reported on the variation in six characteristics. Here we have considered 15 characteristics and selected nine specimens each from New South Wales, northern Australia, West Australia and southern Australia. The nine specimens from northern Australia were taken from a single collection from the Torres Straits to determine variation within a limited population; the others were to determine if there were enough differences in geographically separated populations to warrant their consideration as subspecies. The results are given in Table V.

The specimens from the Red Sea conformed well to Paulson's description in all points and did not show variation as great as did the specimens from Australia. Most had a strong superior tooth on the basicerite above the dactylar articulation of the large chela, and relatively strong posterolateral teeth on the telson. However, in this small collection variation was noted—for example, the posterolateral teeth on the telson varied from as long as Paulson depicted to as short as the longest from Australia. Thus, we believe that the population in the Red Sea shows the potential of variation we are reporting, but the variation is more muted.

These results confirm our earlier opinion that the species is very variable, and that *S. hululensis* is a synonym of *S. tumidomanus*. The variation easily encompasses the lectotype established for *S. hululensis hululensis* by Crosnier and Forest. We will leave to those authors the decision on the best way to treat their two Atlantic subspecies, whether they should be continued as subspecies of *S. tumidomanus* or raised to specific rank. (We regret we were unable to refer to the important paper of Crosnier and Forest in our 1968 study, for we received our copy of their work when our paper was at the publisher in Japan.)

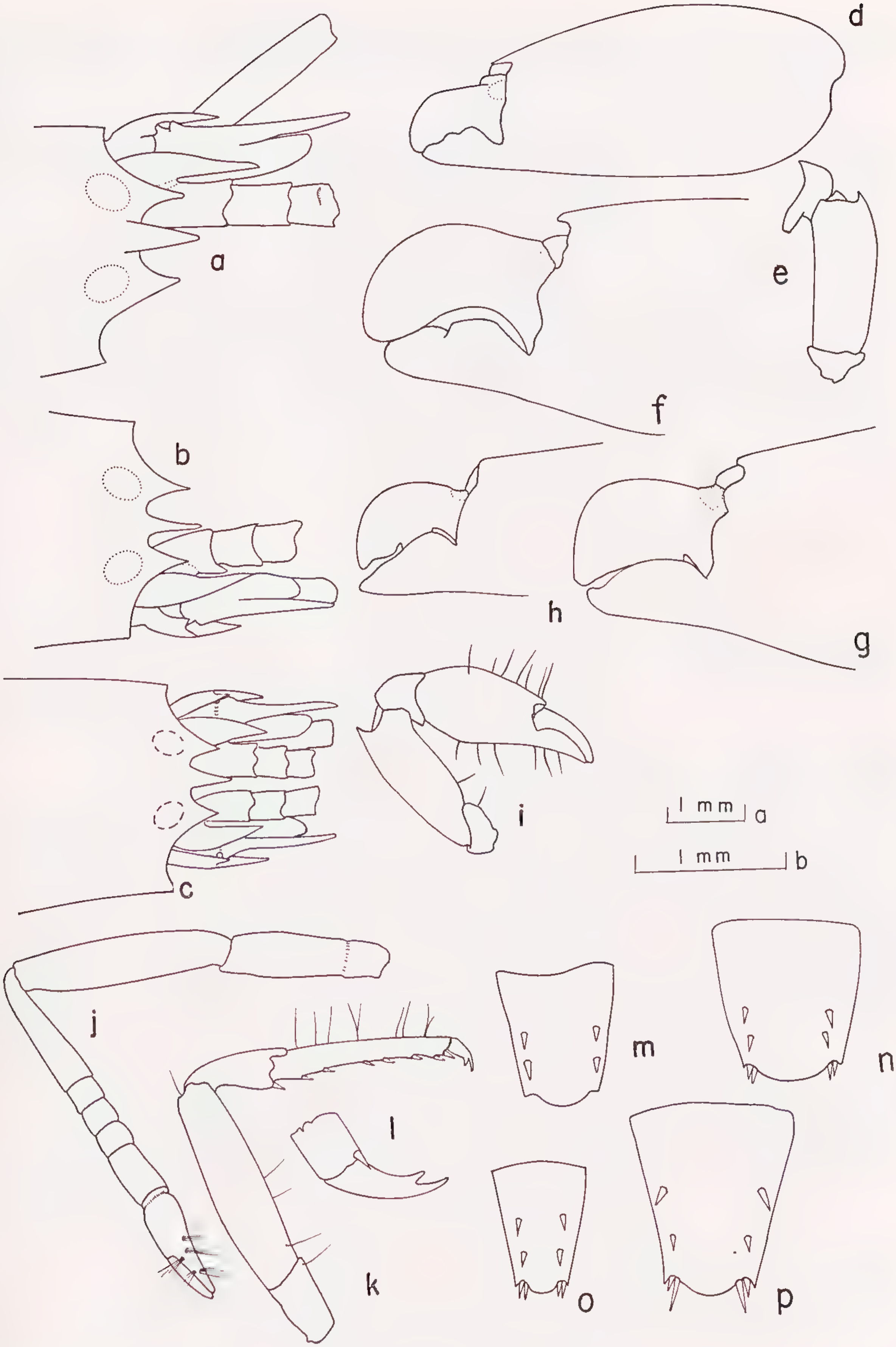
Two other nominal species should be considered. The first was described as *Synalpheus maccullochi* by Coutière from the coast of "S. W. Australia". This species was distinguished from *S. paulsoni* Nobili by having eggs of greater volume and from *S. tumidomanus* by the lack of strong tooth on the basicerite and the lack of teeth on the posterolateral angles of the telson. Through the courtesy of Mme. Laurent of the Muséum National d'Histoire Naturelle in Paris we were able to examine seventeen specimens from Australia that Coutière had identified as *S. maccullochi;* six came from the type locality, five came from Nelson's Bay, and six came from an unspecified area in South Australia. We have also examined six female specimens loaned to us by the South Australian Museum that Hale (1927b: 308) had reported as this species from Kangaroo Island, South Australia. All specimens fell within the range of variation we have discussed for *S. tumidomanus* and the species has been placed in synonymy to *S. tumidomanus*. We should also note that the use of egg size is not a good criterion for species separation, for as Brooks and Herrick (1891: 377) first noted, poecilogony exists in the Alpheidae, and as we point out (1968: 277) the eggs grow both larger and more elongate as the embyro matures. We observed this difference in both Coutière's specimens and in Hale's; in the latter of the five ovigerous females, two specimens had conspicuously larger eggs and in those eggs the eyespots were large and dark.

The other species is *S. anisocheir* Stebbing (1915: 86) from South Africa. Barnard (1950: 736) suggested that it was closely related to *S. hululensis*. We could find no characteristics in the descriptions or figures that would separate this species from the range of variation that we had found for *S. tumidomanus*. The two characteristics somewhat emphasized by Stebbing (he compared his species to no other) were the disproportionate sizes of the large and small chelae and the proportions of the articles of the second leg. These cannot be used to distinguish his form from *S. tumidomanus*. Barnard (1950: 736) described and drew the orbitorostral process "Rostrum with ventral prolongation (fig. 139e)" as a specific characteristic; we have compared his description to the process in our specimens and found them to be similar, if not identical (Banner & Banner, in preparation).

On the basis of the figures given by Fourmanoir of specimens he identified as *S. anisocheir,* we cannot determine the species he was studying, but the form of the orbital teeth and chela indicate it may be in the genus *Alpheus* which precludes the possibility that it is *S. tumidomanus*.

OPPOSITE

Fig. 28.—*Synalpheus tumidomanus* (Paulson). Variation in specimens from Australia. a, b, c, anterior region of carapace; d, e, f, g, h, large chelae (d and e same specimen); i, small cheliped; j, second leg; k, l, third leg and dactylus; n, m, o, p, telsons. a, b, c, d, e, f, g, h, i, j, k, m, n, o, scale a; l, p., scale b.


a
b
c
d
e
f
g
h
i
1 mm a
1 mm b
j
k
l
m
n
o
p

Upon studying specimens of *S. tumidomanus* in Japan, Miya (1972: 65) reached the conclusion that *S. japonicus* was also a synonym; he further accepts the variation we had described in 1968 as applying to the Japanese specimens.

Biological notes: Our specimens have been collected from the intertidal zone to waters up to slightly over 81 fathoms deep, from the heads of dead coral and from sponges. Our specimens ranged in size from 10–25 mm.

Australian distribution: *S. tumidomanus* has been found off all shores of Australia and at Norfolk Island and Lord Howe Island, Tasman Sea.

General distribution: In the Indo-Pacific the species is known (under various names) from South Africa; Red Sea; Persian Gulf; Ceylon; Maldive Archipelago; Singapore; Thailand; Indonesia; Philippines*; Japan and across the central Pacific to the Phoenix Archipelago. It has also been found on the Mediterranean coast of Israel. Whether it or closely related species occur in the Atlantic and eastern Pacific remains to be determined.

Synalpheus paraneomeris Coutière

Fig. 29

Synalpheus paraneomeris Coutière, 1905a, Fauna and Geog. Mald. and Laccad. 2 (4): 872, pl. 71, fig. 7. Banner, 1953, Pacif. Sci. 7 (1): 40, fig. 13, 14; 1956, Pacif. Sci. 10 (3): 331, fig. 6.

Synalpheus paraneomeris halmaherensis De Man, 1909a, Tijdschr. ned. dierk. Vereen 11 (2): 122.

Synalpheus paraneomeris praedabundus De Man, 1909a, Tijdschr. ned. dierk. Vereen 11 (2): 123.

Synalpheus paraneomeris prolatus De Man, 1911, Siboga Exped. 39a[1] (2): 241 [*cf*. Banner 1953: 43].

Synalpheus paraneomeris prasalini Coutière, 1921, Trans. Linn. Soc. Lond. II, 17 (4): 415, pl. 61, fig. 6.

Synalpheus paraneomeris seychellensis Coutière, 1921, Trans. Linn. Soc. Lond. II, 17 (4): 415, pl. 61, fig. 7.

Synalpheus townsendi Coutière, 1909, Proc. U. S. natn. Mus. 36 (1659): 32 [*partim cf*. Banner, 1953: 44].

Specimens examined: 2 specimens from AM 214; 4, AM 326; 10, BAU 10; 3, BAU 11; 3, BAU 15; 3, BAU 16; 3, BAU 21; 1, BAU 29; 2, BAU 30; 2, BAU 31; 5, BAU 32; 3, BAU 33; 1, BAU 34; 3, BAU 47; 2, BAU 48; 10, BAU 55; 2, BAU 57; 2, BAU 58.

Diagnosis: Rostrum narrow and acute, reaching to near end of first antennular article. Orbital hoods triangular, acute to subacute, variable in length but not reaching beyond end of rostrum. Rostral base with orbitorostral process.

Second and third antennular article equal, slightly longer than broad; visible part of first article slightly longer. Stylocerite reaching from near base to near end of second antennular article. Lateral tooth of scaphocerite variable, longer than antennular peduncle; squamous portion variable in breadth and length, reaching to or beyond middle of third antennular article. Carpocerite usually 5.0 times as long as broad, reaching beyond end of third antennular article. Inferior spine of basicerite a little shorter than stylocerite, superior margin not produced.

Large chela subcylindrical, 2.6 times as long as broad, fingers occupying distal 0.3. Superodistal margin of palm at most slightly produced. Merus 3.0 times as long as broad, superior margin often produced into a small acute tooth. Small chela three times as long as broad, fingers shorter than palm, dactylus not broadened. Merus similar to that for large chela.

Carpal article of second legs with ratio: 10:1:1:1:3.

Merus of third legs four times as long as broad, unarmed. Carpus 0.4 as long as merus, distosuperior margin projected as tooth, inferodistal margin bearing spine. Propodus almost equal to merus, bearing 4–5 slender spines on inferior margin and two distally. Dactylus biunguiculate, with inferior tooth usually

a little shorter and broader at base than superior unguis. Dactylus often slightly expanded with inferior margin convex proximal to inferior unguis, as if it were a vestige of a third unguis.

Telson 2.2 times as long as posterior margin is broad, posterolateral margin forms right angles or slight rounded projections, inner pair of posterolateral spines long and slender, over twice length of outer pair. Spinules on upper surface small and lying posterior to middle.

Discussion: Although Coutière in his original description remarked on the variation in some of the characteristics, he described two additional varieties and De Man described three varieties of the species. All were described on the basis of but few specimens. The junior author, first with 100 specimens from Hawaii (1953) and later with 90 specimens from the Marianas (1956) pointed out the wide range of variation found within the populations of this species and discarded the varietal names as they appeared to be merely designations of individuals within the normal span of variation. Collections studied later made no changes in this assessment. In his earliest paper, the junior author also reported that the single broken specimen that Coutière had reported from Hawaii as *S. townsendi*, an Atlantic species, appeared to be *S. paraneomeris*.

The Australian specimens also show similar variability in proportions and have several not previously remarked upon. Thus, some from Australia have a slight rounded projection above the dactylar articulation on the large chela, a characteristic not reported from Hawaii or the Marianas. Two characteristics, variable in other populations, appear to be more fixed in the Australian specimens: first, the superior margin of the meri of the large and small chelae always projected as a small acute tooth in the Australian specimens, but only occasionally did so in the Hawaiian specimens; second, the inner pair of spinules of the posterior margin of the telson was consistently much longer than the outer pair in the Australian specimens, while in other collections studied the inner pair at times was only slightly longer than the outer pair.

Miya (1972: 54) pointed out that in the Japanese specimens of *S. paraneomeris* the posterolateral corners of the telson were spiniform; a characteristic we have not observed in our collections. Further, his specimens do not appear to have the inferior margin of the dactylus of the third legs slightly convex proximal to the inferior unguis. Perhaps this may indicate a geographically isolated subspecies.

Biological notes: All the Australian specimens were taken from dead coral heads in water up to 15 ft, except for two specimens that were taken by trawl at 11 fathoms. The deepest record for the species was the one identified by Coutière as *S. townsendi*, taken by trawl in Hawaii at 69 fathoms; however, as it was without major thoracic appendages, its identification was not certain.

Banner reported (1953: 41) "Colour typically olive brown to grey, but those living in heads of *Pocillipora meandrina* reddish". Yaldwyn in field notes (AM 326) stated "Body and appendages greenish, transparent with scattering of small red chromatophores. Eyes black; tips of fingers green and eggs green". Our specimens ranged from 7–15 mm in length, most specimens being around 10 mm.

Australian distribution: All Australian specimens were collected from north eastern Australia and the Great Barrier Reef from near Cairns southward to off Cape Moreton, near Brisbane.

General distribution: Maldive Archipelago; Indonesia; Japan; Philippines*; Mariana; Caroline; Marshall; Gilbert; Fiji; Samoa; Line and Hawaiian Islands. The species was not found in our Malayo-Thai collections.

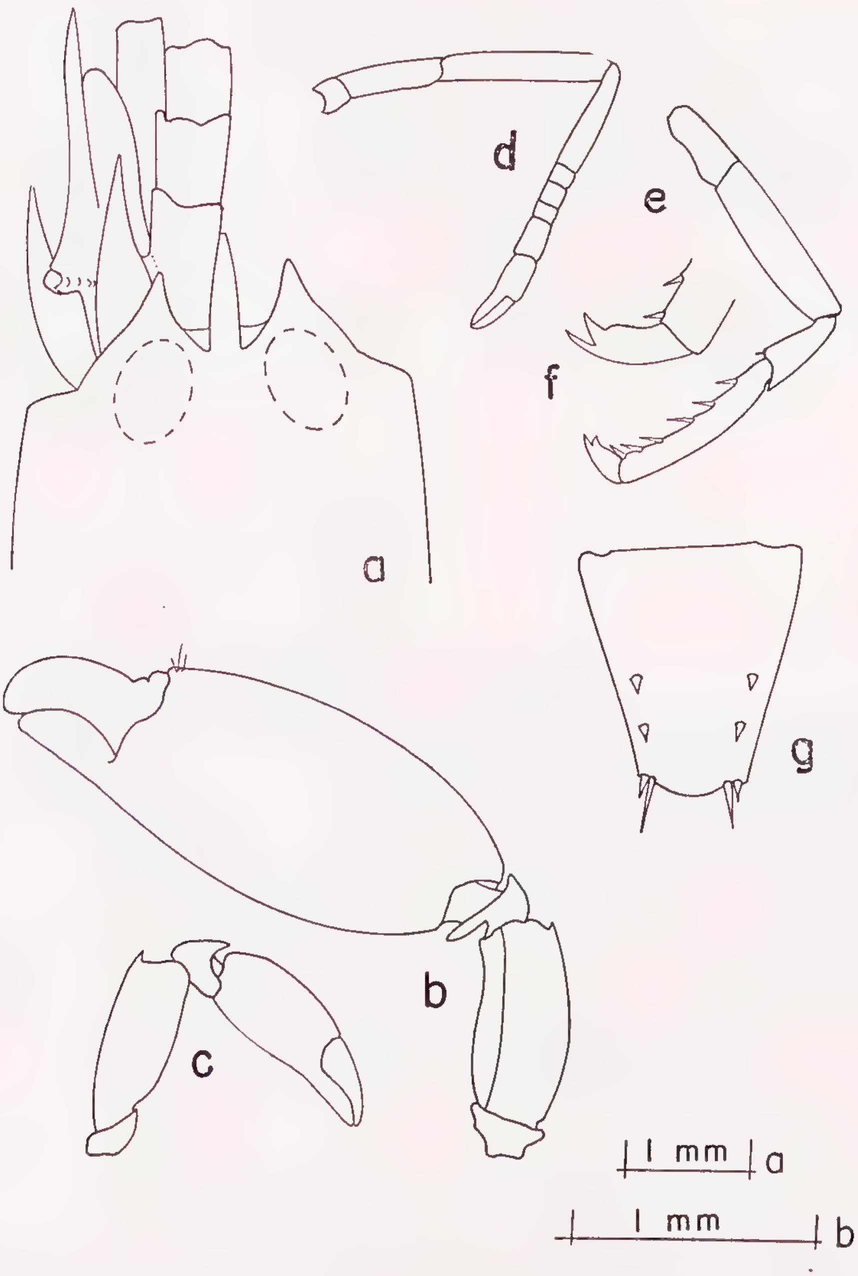


Fig. 29.—*Synalpheus paraneomeris* Coutiere. 10 mm female from BAU 55. a, anterior region, dorsal view; b, large cheliped; c, small cheliped; d, second leg; e, f, third leg and enlarged dactylus; g, telson. b, c, d, e, scale a; a, f, g, scale b.

APPENDIX

Alpheids Associated with Crinoids

A number of species of alpheids, mostly synalpheids of the Comatularum group, are known to live upon the comatulid crinoids or feather stars. Some appear to be obligate symbionts; others appear to prefer the symbiotic association but may live freely; some appear to be on the crinoids by a matter of chance. As we have remarked in the Introduction (p. 277) we suspect that collection data may not show the true association, for the shrimp may be dislodged from the crinoid in the collecting, particularly in the hauling of a dredge. In some cases the collector may have even separated the shrimp from the host without noting the association in his locality notes.

The following Australian species are known to be associated with crinoids (for synonymy, see main text):

Athanas indicus (Coutière)

Synalpheus comatularum (Haswell)

Synalpheus stimpsoni (De Man)

Synalpheus carinatus (De Man)

Synalpheus demani Borradaile

In addition the Australian *S. tropidodactylus* which is morphologically closely associated with the first three species of *Synalpheus* may also be associated with crinoids, for the only two specimens known were collected by dredging and may have been dislodged from a crinoid in the process. Of the non-Australian members of the specialized Comatularum group, *S. odontophorus* was reported originally by De Man (1911: 208) from Indonesia and later by Miya (1972: 51) from Japan in dredge hauls without any indication of symbiotic associations; however we have specimens yet unreported, from the South China Sea which came from crinoids. Thus in the Comatularum group of Coutière, five of the six presently recognized species are definitely, or may be, associated with crinoids. The sixth species of the group, *S. albatrossi* Coutière, probably is not in such an association for it is known only from the Hawaiian Archipelago where shallow-water crinoids do not occur.

Of the two species reported from crinoids not in the Comatularum group, *Athanas indicus* (Coutière) and *Synalpheus demani*, little can be said. *Athanas indicus* is normally associated with echinoids (see Part I, p. 329), but a specimen collected from Swains Reefs (AM 392) was reported to be taken from a crinoid. *Synalpheus demani* in Australian waters is known only from dredge hauls, but we (Banner & Banner 1968: 274) have reported it from crinoids in the Marshall Islands. Miya (1972: 62) has recorded that all of his Japanese specimens "were living in association with *Comanthina schlegeli* (Carpenter)".

It should be noted that Johnson (1962a: 49) lists *Athanas jedanensis* De Man, *Synalpheus acanthitelsonis* Coutière, *Synalpheus quadrispinosus* De Man, and *Alpheus paralcyone* Coutière as occurring in "crinoid grounds" and he suggests they may be symbionts upon the echinoderms; these species have not elsewhere been so reported. Finally a specimen of *Alpheus edwardsi* (Audouin) was reported by C. Smalley (CS 31) as being upon a crinoid in Western Australia; we have not considered it here because obviously this is not the normal habitat for this well-known and often-collected species.

A number of authors have remarked on the association of the shrimp with the crinoids, most especially Potts (1915a, b) working in Torres Straits, and A. H. Clark (1921) who not only reviewed all previous reports, but also added his own personal observations. Most of the observations were limited to *S. stimpsoni* (named by Potts *S. brucei*) and *S. comatularum*. According to Clark the shrimp are "semiparasitic commensals" which have "to a greater or less extent adopted the sucking up of food particles from the streams flowing down the ambulacral grooves of the crinoids to the mouth." Potts pointed out that the shrimp are afforded protection from predators by the crinoid which folds its arms over the disc—and the shrimp—when disturbed. Clark stated that the most heavily infested family of the crinoids are the large and shallow water comastreids of the Indo-Pacific, which, unlike many other families of crinoids, lack plates and spines to cover the ambulacral grooves and thus protect their food supply.

While Potts was primarily concerned with color patterns, he had other observations on the biology of the shrimp (1915a): They live as mated pairs, normally on the disc facing towards the mouth. When disturbed they take refuge on the underside of the arms. They resist displacement by digging into the flesh of the host with the hook-shaped dactylus of the small chela of *S. comatularum* and by the sharp, curved biunguiculate dactyli of the third to fifth thoracic legs of *S. stimpsoni*. When displaced, they will attempt to return immediately to their host, but if it is not available, they will shun light and approach any other objects, whether living subjects or not. If a group of them are kept in a glass dish, all will cling together. Potts also remarked on zonation in the Torres Straits, with *S. stimpsoni* occupying the upper zone in the reef and *S. comatularum* being dominant below 5 fathoms. (We have records of the latter species being collected intertidally.)

Potts pointed out that both species inhabit two species of crinoids, *Comanthus timorensis* and *Comatula purpurea;* the former crinoid species is extremely variable in color, ranging from pale green through banded to a dark green; the latter species is red. Potts observed that the shrimp had bright red and dark purple, almost black, chromatophores, and that (presumably by contraction of the chromatophores) the shrimp could become almost transparent. In almost all cases the color of the shrimp on any individual crinoid was adjusted to blend completely with the color of the host, usually in the form of pigmented longitudinal stripes against the transparent, or white, background. In a few cases he observed contrasting coloration which he interpreted to be that of a new arrival from a crinoid of a different color. He remarked that in his preservative mixture of formalin and glycerine, the purple pigment dissolved, but the red color remained fixed in the specimens. Clark gave other similar examples of protective coloration.

Key to the species of alpheids known to live on or or suspected of living on crinoids as symbionts

1. Eyes dorsally and laterally exposed .... *Athanas indicus* (pt. 1, p. 327)

— Eyes covered by orbital hoods...................... (*Synalpheus*)

2. (1) Dactylus of third leg biunguiculate; without orbitorostral process.... 3

— Dactylus of third leg triunguiculate; with orbitorostral process...... .... *S. demani* (p. 324)

3. (2) Distoinferior margin of third leg with tooth 4

— Distoinferior margin of third leg inermous 6

4. (3) Dactylus of small chela crescentric, strongly hooked .... *S. comatularum* (p. 289)

— Dactylus of small chela straight 5

5. (4) Fixed finger of large chela bearing strong, flat tooth on medial side.... .... *S. odontophorus*

— Fixed finger of large chela with medial edge rounded, not projecting.. .... *S. stimpsoni* (p. 292)

6. (3) Rostral carina strong and continued almost to posterior end of carapace .... *S. carinatus* (p. 283)

— Rostral carina slight and terminating anterior to eyes .... *S. tropidodactylus* (p. 286)

Note: We recently were loaned a specimen of *Synalpheus* from a crinoid collected near Lizard Island, Queensland that is apparently new. We plan to describe it in Part III of this study.

The Swain Reefs Expedition: CRINOIDEA

By AILSA M. CLARK

British Museum (Natural History)

(Manuscript received 15th March, 1974)

SUMMARY

Eighteen species of crinoids collected at the Swain Reefs, 21° 43′ S. : 152° 25′E.; N.E. of the Capricorn Channel, are discussed, one of these, the unusual five-armed *Eudiocrinus serripinna* A. H. Clark, representing a genus new to the Australian fauna. The range of two other species, *Oligometra serripinna* (P. H. Carpenter) and *Ptilometra australis* (Witton), are extended into Queensland waters by the expedition's work.

INTRODUCTION

Some difficulty is involved in the identification of Australian crinoids because of the frequent differences of opinion between the crinoid specialist, Mr A. H. Clark, working on preserved material, and Dr H. L. Clark, whose interests were wider but who had considerable experience of live echinoderms of Australia, though less of crinoids as a group. Being in the same position as A. H. Clark, without knowledge of the species in life, I have tended to follow his dispositions of the species to a greater extent than those of H. L. Clark. Nevertheless I should state that I consider the number of valid species could be reduced further, the distinction between at least four pairs of nominal species being poorly-founded. These are *Comatella nigra* and *stelligera, Comatula pectinata* and *purpurea, Zygometra microdiscus* and *elegans* and *Lamprometra palmata* and *gyges.* (The last two are treated here as subspecies.) An intensive study of variation, growth changes and ecology is needed to clarify the relationships of these.

The references in the text have been kept to a minimum since full details are given in A. H. Clark's crinoid monograph.

All the crinoids were collected in the vicinity of Gillett Cay; those from station 1 on the reef and sand flats, while stations 5 and 6 are in 27–37 and 64–73 metres respectively.

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COMASTERIDAE

Comatella nigra (P. H. Carpenter)

Actinometra nigra Carpenter, 1876: 583; 1888: 304.

Comatella nigra.—A. H. Clark, 1908b: 208; H. L. Clark, 1921: 12–13.—A. H. Clark, 1931: 92–98; fig. 1–31.—H. L. Clark, 1932: 198; 1946: 25–26.

Material

Capre Cay, 1 specimen; station 6, 4 specimens.

Remarks

This very ill-founded nominal species could be cited as *C. nigra* (Semper *in* Carpenter) since Carpenter consistently referred to it only as "Semper MSS" and never gave a formal description. It is debatable whether his brief remark about the internal anatomy of the arms in 1876 is sufficient indication to establish the name but in 1888 he did distinguish it from the three other species of the "stelligera-group" in a short key. It is, therefore, unfortunate that A. H. Clark in 1908 designated *Actinometra nigra* as type-species of *Comatella* rather than the better-known *stelligera*. The type-material of *C. nigra* must be Semper's specimens from Bohol, Philippines, which were deposited in the Dresden and Vienna Museums.

H. L. Clark (1946) gives only three Australian records of *Comatella nigra,* all identified by himself, from the Abrolhos, from Mer, Torres Strait and from Lizard Island, off N. Queensland, collected by the Great Barrier Reef Expedition. All other Australian specimens of *Comatella* he has referred to *C. stelligera.*

A. H. Clark's key to the species of *Comatella* (1931: 91–92) distinguishes *nigra* as having the cirrus segments "usually 26–30; arms usually more than 40" in comparison with *stelligera* with "usually 20–25 cirrus segments; usually 30–40 arms". The five specimens from Swain Reefs have respectively c. 45, 43, c. 40, 40 and 29 arms with up to 26, 27, 31, 25 and 27 cirrus segments, in general approximating more to *C. nigra.* I can see no good reason for distinguishing the last one specifically from the other four; in comparison with a syntype of *C. stelligera* from the Fiji Islands, having 26 arms, it has the division series and arm bases much less stout and widely separated from each other laterally. However, the arm length in the Swain Reefs specimens is only c. 70 mm, whereas in the type of *C. stelligera* it is 60 +(?) c. 30–40 mm. The smaller size of the former probably accounts for the greater smoothness of the division series and arm bases, the larger specimens from Swain Reefs having these ossicles much more rugose; also their more numerous arms leave little room between them laterally. The specimens from the Great Barrier Reef collection are certainly conspecific with those from Swain Reefs and I suspect that comparison of really good samples from the Philippine area (the type-locality of *C. nigra*) and from Australia and the Fiji Islands will show that the range of variation in arm number and cirri is such that two species cannot be differentiated. Unfortunately, I have no Philippine material available for study.

Colour notes for four out of five specimens describe them as deep or dark red with bright green tips to the arms in life.

Comatula Lamarck

Comatula Lamarck, 1816: 530–533.—A. H. Clark, 1931: 302–308.

Type species: *C. solaris* Lamarck, 1816.

A. H. Clark (1931) recognizes no less than six species of the ten-armed *Comatula* sensu stricto (i.e. excluding the subgenus *Validia*), of which four have been recorded from tropical Australia; of these he notes that "undoubtedly *C. cratera* is merely a form of *C. solaris,* related to it in much the same way that *C. purpurea* is to *C. pectinata*". His key to the species is based solely on the occurrence and development of the cirri, which show considerable individual as well as ontogenetic variation in many comasterids, notably in *Comanthus parvicirrus.* The type-species, *Comatula solaris,* is supposed to be distinguished by the relatively well-developed cirri with 16–25 segments. However, I think it is significant that A. H. Clark includes no mention of any specimens referred to *solaris* with arm length less than 90 mm, whereas for *Comatula pectinata* with not more than 16 cirrus segments both small and large specimens are described. Surely some of these must be immature individuals of what would be called *C. solaris* if more fully grown. Conversely, the relatively small number (15) of *Comatula cratera* recorded by A. H. Clark show more or less extreme reduction of the cirri, ten of them having none at all and the rest only a few probably functionless ones, while the arm length is 175 mm or more. This could represent a parallel to *Comatula (Validia) rotalaria* Lamarck* in which small specimens possess cirri but these are progressively lost as the size increases. *C. solaris* then results from neotenous individuals which have retained and increased the size of their cirri, possibly in response to life in more active water necessitating better anchorage. Clearly a special study of the variation and growth changes of local populations of *Comatula* is needed to clarify the limits, if any, between the nominal species which have been described.

The 40 specimens of *Comatula* from Swain Reefs are all relatively small, arm length about 45 mm, the largest only about 70 mm. With three exceptions all of these run down to *Comatula purpurea* (J. Müller) in A. H. Clark's key since they have incomplete rings of cirri around the centrodorsal. The three remaining specimens not only have complete rings of cirri as in *C. pectinata* (Linnaeus) but also appear to have the division series and arm bases more nearly cylindrical in cross-section than in any of the former specimens, at the same time lacking the median longitudinal ridge on the arms. However, this last feature is variable and such ridges have been described in several specimens attributed to *pectinata,* including Linnaeus's type-material. The correlation between the dorsally-flattened ossicles of *purpurea* and the incomplete cirrus ring needs further investigation in other large samples. Another character which should be taken into consideration is the form of the comb on the basal pinnules, which Gislén found to be shorter in *C. purpurea.*

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* The subgenus *Validia* of A. H. Clark is distinguished from *Comatula* sensu stricto by the development of ten additional arms at a relatively late stage in ontogeny. H. L. Clark (1938) raised *Validia* to generic rank but I am not sure that this is justified; certainly the arm structure in the two is very similar.

Gislén (1919) has treated *purpurea* as a variety of *C. pectinata* and this could well be preferable to according its specific rank. However, pending additional study I am following A. H. Clark's usage at present, even though another Australian specimen of *Comatula* (sent for identification simultaneously) collected in the Gulf of Carpentaria, is intermediate between *purpurea* and *pectinata,* having only small gaps in the ring of cirri. H. L. Clark in 1946 synonymized the two, having earlier (1938) retained *purpurea* as a form of *pectinata.*

Comatula purpurea (J. Müller)

Alecto purpurea J. Müller, 1843: 132.

Comatula pectinata var. *purpurea.*—Gislén, 1919: 6–9.

Comatula purpurea.—A. H. Clark, 1911a: 451.—H. L. Clark, 1921: 14–15.—A. H. Clark, 1931: 360–372, figs 108, 109, 111, 114.

Comatula pectinata forma *purpurea.*—H. L. Clark, 1938: 19, 20.

Comatula pectinata (part).—H. L. Clark, 1946: 31.

Material

Station 1, 12 specimens; station 6, 25 specimens.

Eighteen of these specimens have notes of the colour in life; for ten of them this is given as dark red, deep red, brown (once) or bright red (once); eight others show a combination of red or brown with cream, yellow or orange. This is probably just a superficial impression of colour and the angle of assessment is not given. Judging from a colour transparency, the soft (ventral) upper parts are predominantly dark red, which may be consistent. The dorsal side (lower most in life) on the specimen photographed is almost pure white with small red dots under magnification and distally there are larger reddish areas, though these may be partly the reflexed soft parts.

Comatula pectinata (Linnaeus)

Asterias pectinata Linnaeus, 1758: 663.

Comatula pectinata.—Gislén, 1919: 6.—H. L. Clark, 1921: 14, pl. 1 fig. 3, pl. 3 fig. 2.—A. H. Clark, 1931: 339–360, figs 49, 100–107.—H. L. Clark, 1938: 18–20; 1946: 31.

Material

Station 6, 3 specimens.

Comanthus A. H. Clark

Comanthus A. H. Clark, 1908a: 220.—H. L. Clark, 1921: 16.—A. H. Clark, 1931: 527–531.

Type-species: *Comanthus intricata* A. H. Clark, 1908, a synonym of *C. parvicirrus* (J. Müller).

A comment on the gender of the name *Comanthus* is needed. H. L. Clark (1921) noted that the greek word anthos is neuter but since, he said, A. H. Clark had used the feminine termination for the specific names he included in the genus in 1908, he himself would henceforth adopt the feminine gender. However, the International Code of Nomenclature, article 30 (3), dealing with genus-group names ending with a greek word, states that if this greek word is latinized with a change of termination (as in this case from os- to -us), it takes the gender appropriate to that termination, in this case masculine. The specific name *samoana* is accordingly modified here to *samoanus*, being an adjective in the nominative. However, *trichoptera*, being a noun in apposition, remains the same. Although *parvicirra* is also a noun in apposition I think it should have taken the masculine ending in the first place since cirrus is masculine, so this too is changed. A. H. Clark made a practice of retaining original terminations and spellings of specific names even when transferring them to genera of other genders, which conflicts with the rules now followed.

The division of the genus *Comanthus* into two subgenera, *Comanthus* and *Cenolia,* by A. H. Clark, the latter subsequently (1946) raised to generic rank by H. L. Clark following remarks of Gislén, seems to me quite untenable in view of the great variation of cirrus development in *Comanthus parvicirrus*. Gislén was prompted to support the division on the basis of differences in the pinnule combs but, these too have been shown to be extremely variable in *C. parvicirrus*. Even A. H. Clark himself (1931: 662) has noted that *Comanthus* (*Comanthus*) *parvicirrus* and *C.* (*Cenolia*) *samoanus* intergrade and in dealing with Australian crinoids I have had some difficulty in deciding which name to use for some of the specimens of *Comanthus*. Although I cannot trace a published mention of his final conclusion about the distinctness of *C. parvicirrus* and *timorensis,* in a letter to me written in the early 1950's, A. H. Clark admitted that he no longer felt able to distinguish two species on the basis of arm number and the occurrence of functional cirri, these characters being too variable. It seems to me likely that the more restricted range of what has been called *C. timorensis* is attributable to enhanced growth involving multiplication of the arms, correlated with further reduction of the cirri in localities where the optimum conditions obtain; in the more outlying parts of the range, development does not proceed beyond the usual *parvicirrus*-form with about twenty arms and retaining small and more or less functional cirri.

Here again, the tropical Australian species of the genus need further critical study including detailed attempts to correlate the various characters. The geographical and morphological limits between *Comanthus parvicirrus* and *C. samoanus* on the one hand and the temperate *C. trichoptera* on the other should be investigated.

Comanthus parvicirrus (J. Müller)

Alecto parvicirra J. Müller, 1841: 185.

Comanthus parvicirra.—A. H. Clark, 1911a: 443.—H. L. Clark, 1921: 19, pl. 1, figs 5, 7.—A. H. Clark, 1931: 631–684, figs 88, 184, 200, 209–218, 221.—H. L. Clark, 1938: 26; 1946: 39.

Alecto timorensis J. Müller, 1841: 186.

Actinometra annulata Bell, 1882: 535, pl. 35.

Comanthus annulata.—A. H. Clark, 1911a: 443.—H. L. Clark, 1921: 16, pl. 1 figs 2, 8, pl. 3 fig. 3.

Comanthus (*Vania*) *annulata*.—A. H. Clark, 1911a: 457–458; 1911b: 757–1918: 53–54.

Comanthus (*Vania*) *parvicirra*.—A. H. Clark, 1911b: 758–1918: 54–59.

Comanthus timorensis.—A. H. Clark, 1931: 603–631, figs 181, 204–207.—H. L. Clark, 1938: 27–28; 1946: 38–39.

Material

Station 1, 1 specimen; station 6, 7 specimens; Capre Cay, 1 specimen.

A colour note of the specimen from station 1 states that the arms were dull green at the base gradually lightening to bright green distally. One from station 6 was "green and white".

The specimen from Capre Cay has the cirri fairly well developed, numbering about XX and forming a complete ring around the centrodorsal, though some sockets appear to be becoming obsolete. The cirri are not much compressed laterally, though the larger ones are incurled in their outer part. This condition is also found in the specimen from station 1 and seems to me transitional to *C. samoanus* with its short incurled cirri normally stouter than is usual in *C. parvicirrus*. The specimens from station 6 show much variation, two have all the cirrus sockets more or less obsolete while at the other extreme there are about X laterally compressed cirri in a more or less complete ring, though this condition appears to be correlated here with the relatively smaller size.

Comanthus sp. **Cotrichoptera** (J. Müller)

Comatula trichoptera J. Müller, 1846: 178.

Comanthus (*Bennettia*) *trichoptera*.—*A. H. Clark,* 1911*a*: 456–457; 1911*b*: 755–156.

Comanthus trichoptera.—A. H. Clark, 1938: 28–29.

Comanthus (*Cenolia*) *trichoptera*.—A. H. Clark, 1931: 579–587, figs 4, 203.

Material

Station 1, 1 specimen; station 6, 2 specimens.

All three specimens are relatively small, arm length 30–60 mm, and are distinguishable from *C. parvicirrus* by the more prolonged angles of the axillaries. Their cirrus rings are also complete.

As for colour, one is described as bright yellow and another is shown as yellow in a colour transparency. This agrees with *C. trichoptera* which H. L. Clark notes is generally yellowish though ranging from white to brown. However, H. L. Clark has also noted a yellow form (*xantha*) of *C. timorensis* (i.e. *parvicirrus*) occurring in Torres Strait.

If the identification as *C. trichoptera* is correct, it means an extension of range northwards from Lord Howe Island.

Comantha perplexa (H. L. Clark)

Comanthus perplexum H. L. Clark, 1916: 14–15, pl. 3 fig. 2.

Comantheria perplexum.—A. H. Clark, 1931: 506–507; H. L. Clark, 1938: 25; 1946: 35.

Material

Station 6, 1 specimen.

This specimen has 36 arms, c. 80 mm long and with an arm breadth at the first syzygy (on arms following a IIIBr series) of 1.85 mm. Four of the IIBr series are of two ossicles only, the remaining six are of four. Of the fourteen IIIBr series present, eleven have only two ossicles, as is characteristic of *Comantheria* as opposed to *Comanthus* in which the majority usually have four. There are two IVBr series, one of two ossicles, the other of four.

There are XIV cirri still present plus about v diminutive ones or recently emptied sockets (which A. H. Clark would not have counted). The mature cirri have 20 or 21 segments and are about 13 mm long. After the few basal ones, the segments to about the twelfth are longer than broad; the twelfth to sixteenth show two dorsal processes when viewed in profile, one proximal one distal, but these approximate as the segments shorten and coalesce on the seventeenth segment leaving a single curved transverse ridge with two or sometimes three small spines emphasizing it on the last two segments before the terminal claw.

The ossicles of the division series are not markedly flared although the arm segments do have some tendency this way, becoming slightly spinose along their distal edges.

The colour in life was noted as very dark red with green tips. This does not accord either with the "uniformly pale fawn" of the dorsal side in the holotype, though this was in the dried condition and the colour in life could well have been very different, or with some specimens in the British Museum collections from Mooloolabah in southern Queensland, the subject of pigment studies by Dr Sutherland of the Chemistry Department of the University of Queensland, which were yellow in life. At first I thought this Swain Reefs specimen was referable to *Comanthus parvicirrus* but the high proportion of IIIBr series of only two ossicles and the double dorsal processes on some of the cirrus segments incline me to refer it to *Comantheria perplexa*. H. L. Clark, (1938) has already recorded the species from the adjacent Capricorn Islands.

Three of the specimens from Mooloolabah have the following counts: arm number 33, 32 + c. 5, 30++; the first has arm length c. 80 mm, and all three have the arm breadth at the first brachial syzygy c. 1.75 mm; the cirrus number is VII + vi, V + vi, and VIII + viii, the larger mature cirri having 20 or 21 segments in all of them and measuring 10–13 mm in length; one of the three has a single IIBr series of only two ossicles and all of them have all the remaining IIIBr series of only two ossicles. In comparison with the specimen from the Swain Reefs, the division series and arm bases are smoother, while the cirri are slightly stouter and smoother dorsally with low rounded processes, none of the segments showing a distinct proximal process though the penultimate segment has the distal process paired.

ZYGOMETRIDAE

Zygometra elegans (Bell)

Antedon elegans Bell, 1882: 534; 1884: 162, pl. 13 fig. B.

Zygometra elegans.—A. H. Clark, 1911a: 458–459; 1911b: 762–763.—H. L. Clark, 1916: 18–19; 1938: 31–32.—A. H. Clark, 1941: 98–110, figs 5, 7–12.
—H. L. Clark, 1946: 40–41.

Zygometra microdiscus var. *elegans*.—Gislén, 1919: 19–23.

Material

Station 6, 3 specimens.

The colour notes from life are "yellow and cream with purple tips", "cream and deep purple" and "cream and purple-brown".

Zygometra punctata A. H. Clark

Zygometra punctata A. H. Clark, 1912a: 24–25.—H. L. Clark, 1932: 200–201. —A. H. Clark, 1941: 120–123, figs 18–21.—H. L. Clark, 1946: 41.

Material

Station 6, 2 specimens

The colour in life is given as "yellow with very narrow brown bands on the arms" for one specimen which in spirit is pale with purple spots, agreeing with the preserved colour of the holotype; a transparency of the second specimen shows it as golden brown with a lighter band across each ossicle, probably along the distal edge.

H. L. Clark (1946) suspects that *Z. punctata* will prove to be indistinguishable from *Z. comata,* known in Australia only from the northwest, the vicinity of Broome. According to A. H. Clark, *Z. punctata* has short, rather stout, incurled cirri with up to 21 segments only, none of them longer than broad and 10–21 arms, compared with less stout cirri having 25–45 segments, several of which are longer than broad and 14–41, usually 25–30, arms in *Z. comata.* The largest specimens of *Z. punctata* described by Mr Clark have an arm length of only 35 mm compared with 40–135 mm for *comata.* However, I think that any ontogenetic change in shape of the cirri is more likely to be from attenuated in small specimens to stouter in larger ones, rather than the reverse.

The larger of the Swain Reefs specimens has the arms 35+ (probably c. 40) mm long and the breadth at the first syzygy (3 + 4) on arms based on IBr series is 1.5 mm. It only has 11 arms, the single IIBr series having four ossicles, though since two of the IBr series are broken at the syzygy, it is possible that two other IIBr series could have been present and the total number of arms 13. The smaller specimen has only 10 arms. The cirri number about XX, the larger specimen having up to 21 segments and the smaller 20, with dorsal spines from the seventh segment onwards. P_2 is always the largest pinnule. In the smaller speciment P_1, P_2 and P_3 are respectively 5.5 mm, 6.0 mm and 4.2 mm in length with 23, 22 and 16 segments.

A somewhat larger specimen of *Z. punctata* in the British Museum collections from the Low Islands originating with the Great Barrier Reef Expedition and named by H. L. Clark, has all the arms broken within 37 mm of the base but the intact length was probably 50–60 mm. Br at 3 + 4 after the IBr series is 1.75 mm. The arms of two radii are regenerating and simultaneously multiplying by the development of II and even some IIIBr axillaries. Owing to further breakage on capture, the total number of these arms is uncertain but the number of arms on the two radii was at least eight, making a total of 17 with the two, three and four arms developed on the three more mature radii; without the earlier damage provoking regeneration of supernumerary arms the total would more likely have been about 15. Unfortunately, all the cirri are broken off by the sixth segment but some fragments in the jar indicate that there were about 23 or 24 segments in some of the cirri; in form they are stout and strongly incurled, agreeing completely with *Z. punctata,* the higher number of segments being clearly correlated with the larger size in comparison with previously described specimens. Unfortunately, I do not think that the specimen from the same expedition with arms 80 mm long mentioned by H. L. Clark is a *Zygometra* at all; it has a synarthry in the IBr series and P_3 is similar to, or even slightly larger than P_2, though the cirri do have about 21 segment and well-developed single dorsal spines like *Z. punctata.*

In contrast to these specimens from off Queensland, a relatively small specimen of *Z. comata* from Holothuria Bank off N.W. Australia has much more slender, almost straight, cirri with more segments (30–34) though its arm length was probably less than 50 mm, br at 3 + 4 after a IBr series being only 1.3 mm. The difference is so marked that I am sure H. L. Clark is wrong and *Z. comata* and *punctata* are specifically distinct.

EUDIOCRINIDAE

Eudiocrinus serripinna A. H. Clark

Eudiocrinus serripinna A. H. Clark, 1908b: 211; 1941: 169–171, fig. 49.—A. M. Clark, 1972: 90–91, fig. 4.

Material

Station 6, 1 specimen.

The discovery of this unusual five-armed crinoid, recorded in 1972, adds another genus to the Australian echinoderm fauna, previous records of *Eudiocrinus* not approaching nearer than the Pacific islands and of *E. serripinna* not nearer than the Kei Islands.

The colour in life was "light and dark brown". In spirit this has changed to light brown and purple; under magnification the entire surface appears dappled with small patches of colour.

The arms are all broken within 45 mm of the base but were probably 10–15 mm longer than this. Br at 3 + 4 (i.e. between the fifth and sixth free ossicles since in this five-armed genus the "division" series do not in fact divide though the first two ossicles are said to be equivalent to a IBr series) is 1.4 mm.

The discoidal centrodorsal is 2.5 mm in total diameter and 1.9 mm across the dorsal pole. There are XXII cirri or large sockets with perforations (more than half being lost), the longest ones with 17 segments and measuring c. 8 mm in length. Most of the segments, especially the longer ones, are constricted in the middle and flared distally; the fifth to seventh at least are distinctly longer than broad.

The arm ossicles are markedly flared at their distal ends and most have a dorsal tubercle which is midradial on the first ten ossicles but then becomes offset alternately to one side or the other. Since the successive tubercles are linked by a slight ridge along the ossicle, this results in a keeled appearance of the arms, at first straight then zig-zagged, especially as the ridges are paler in colour than the rest. In profile the arms appear very serrated.

The first two pinnules, PC on the left side (facing out from the centrodorsal) of the IBr_2 and P_1 (on the right of Br_2 since Br_1 as usual lacks a pinnule) are very similar with 11 strongly prismatic segments, stout to the sixth and then tapering rapidly. The length is c. 3.7 mm.

Pa and P_2 are abruptly different, more rounded in cross-section except that the distal end of each segment is dramatically flared and spinose. The whole pinnule has 11 or 12 segments and measures 4.25–5.25 mm in length.

Pb and P_3 and the following pinnules are only about two-thirds as long as the immediately preceding pinnules and much more slender though the number of segments is still about 12. The distal ends of their segments are flared and spinose, the third segment particularly having a short dorsal crest.

The disc has been lost.

A. H. Clark recognized no less than seven species of *Eudiocrinus* from the Kei Islands or Moluccas alone, distinguishing them primarily on the proportions of the cirrus segments (which vary to some extent with size) and on the form of the pinnules. I suspect that further material will show sufficient variation to account for some of the supposed differences.

HIMEROMETRIDAE

Heterometra nematodon (Hartlaub)

Antedon nematodon Hartlaub, 1890: 185.

Heterometra nematodon.—A. H. Clark, 1911b: 768; 1941: 241–245, fig. 117.

Material

Station 5, 1 specimen.

This specimen has the arm length only c. 65 mm and 17 (possibly 18) arms, several arms arising direct from IBr series. Correlated with this relatively small size there are only c. 34 cirrus segments; also, in the absence of PD, the largest pinnule is P_2, which has c. 26 segments.

Heterometra crenulata (P. H. Carpenter)

Antedon crenulata P. H. Carpenter, 1882: 507–509.

Amphimetra crenulata.—A. H. Clark, 1913: 22; H. L. Clark, 1916: 21.

Heterometra crenulata.—A. H. Clark, 1918: 79–80.—H. L. Clark, 1932: 201; 1938: 33–34.—A. H. Clark, 1941: 253–275, figs 89–96, 101–103.—H. L. Clark, 1946: 43.

Material

Station 6, 3 specimens, 2 of them immature.

The smaller specimens were "reddish brown and white" in life and the larger "white with faint purple tips".

Amphimetra tessellata discoidea (A. H. Clark)

Himerometra discoidea A. H. Clark, 1908b: 215–216.

Amphimetra discoidea.—A. H. Clark, 1911a: 459; 1911b: 766–767.

Amphimetra tessellata discoidea.—A. H. Clark, 1941: 376–385, figs 178, 182, 188.—H. L. Clark, 1946: 43–44.

Material

Station 6, 4 specimens.

The colour notes of three of these from life are "cream, yellow and dark brown", "cream with purple ribs", "yellow and purple-brown". Transparencies presumed to be of one of these specimens show the colour as predominantly white with about a dozen yellow patches on each arm, the patches marked by paired longitudinal purple lines linked across the intervening white areas by small purple spots.

MARIAMETRIDAE

Stephanometra indica protecta (Lütken)

Antedon protectus Lütken *in* P. H. Carpenter, 1879: 19.

Antedon monacantha Hartlaub, 1890: 179.

Stephanometra monacantha.—A. H. Clark, 1909a: 168–169.—H. L. Clark, 1921: 22; 1946: 46.

Stephanometra indica protectus.—A. H. Clark, 1941: 443–459, figs 222, 225–232.

Material

Station 1, 2 specimens.

One of these had the arms "basally cream, apically (i.e. distally) deep red" in life, the other is patterned with crimson and white in spirit, like some of the specimens of *Lamprometra palmata*, though the spike-like P_2 with only about 12 segments easily distinguishes it.

Lamprometra palmata (J. Müller)

Alecto palmata J. Müller, 1841: 185.

Antedon gyges Bell, 1884: 160–161, pl. 12, fig. B.

Lamprometra brachypecha H. L. Clark, 1915: 104; 1921: 22–23, pl. 2 fig. 1, pl. 22, figs 1, 2.

Lamprometra gyges.—H. L. Clark, 1921: 23, pl. 1, fig. 4, pl. 21, figs 4, 5, pl. 22, fig. 3; 1932: 201–202; 1938: 35–36; 1946: 47.

Lamprometra palmata palmata.—A. H. Clark, 1941: 474–517, figs 243–246, 248–252, 257.

Lamprometra palmata gyges.—A. H. Clark, 1941: 517–526, figs 253–255.

Lamprometra palmata.—H. L. Clark, 1946: 47.

Material

Capre Cay, 2 specimens; station 1, 1 specimen (all three *L. palmata palmata*). Station 6, 3 specimens (*L. palmata gyges*).

Two of the specimens of *L. palmata gyges* have notes of the colour in life; one was dark red, the other yellow, cream and purple-brown.

H. L. Clark (1946) still maintains a specific distinction between *L. palmata* and *gyges* but I doubt whether it is even worthwhile recognizing a subspecific one. Nor am I sure that *L. klunzingeri* (Hartlaub) from the western Indian Ocean can properly be distinguished from *L. palmata,* the form of P_2 (providing the supposed differences) being extremely variable, some specimens of *L. palmata palmata* with P_2 extra stout approximating to *Stephanometra indica* (as suggested by the confused synonymies of *L. palmata* and *S. indica* shown in A. H. Clark's monograph), while conversely those specimens of *L. palmata gyges* with P_2 hardly at all keeled are difficult to distinguish from *L. klunzingeri.*

COLOBOMETRIDAE

Iconometra anisa (H. L. Clark)

Oligometra anisa H. L. Clark, 1915: 105; 1921: 23–24, pl. 1, fig. 10, pl. 4, figs 1, 3, pl. 21, figs 1–3, pl. 36, fig. 1.

Iconometra anisa.—H. L. Clark, 1932: 202.—A. H. Clark, 1947: 97–103, figs 45, 46, 57–61.—H. L. Clark, 1946: 49.

Material

Station 5, 1 specimen; station 6, 2 specimens.

At first sight this ten-armed species can easily be confused with the Antedoninae, the second syzygy being usually at 9 + 10, while the cirri are more compressed laterally than in most Colobometrids. However, the proximal pinnules are distinctly keeled basally on the side facing the arm tip.

The two specimens from station 6 both have the arm length c. 45 mm and br at the first syzygy (3 + 4) is 1.65 mm. The length from the proximal edge of the IBr_1 to the second syzygy at 9 + 10 is c. 8.5 mm. Both have XIX cirri (or newly vacated sockets) with up to 21 segments in one specimen and 22 in the other, the length being 11.0–11.5 mm; most of the segments are about as long as broad and those beyond the base show the rather small transverse "ridges", two on the dorsal side of each segment, characteristic of the species, giving the dorsal profile a double peak on each segment. P_1 has 11 segments and is 6.6 mm long in one specimen and 7.3 mm in the other; unfortunately, none of the other proximal pinnules are intact in the original state though some have regenerated tips, I estimate that P_2 and P_3 probably had at least 15 segments and were over 10 mm long.

The specimen from station 5, however, has an intact P_1 and P_2 on one arm very similar to each other with 8 or 9 segments and c. 3.5 mm long, though it is possible that this P_2 has regenerated; it is slightly stouter than the P_1. This specimen has the arm length only c. 37 mm and not more than 16 cirrus segments.

The previously recorded maximum number of cirrus segments was only 19, even in specimens with an arm length as much as 65 mm. Using A. H. Clark's key to the species of *Iconometra* (1947: 90) the two larger specimens therefore, run down to *I. bellona* (with more than 20 cirrus segments) rather than to *I. anisa* (with less). *I. bellona* (A. H. Clark, 1920) is known from only two Philippine specimens with arm length c. 100 mm. Its cirrus segments have only a proximal transverse ridge on the dorsal side, not a pair. In fact the presence of a distal dorsal ridge or process in *I. anisa* causes it to run down to the monotypic *Oligometrides* in A. H. Clark's key to the genera of *Colobometridae* (1947: 8–9), though the proportions of P_1 relative to P_2 are inverted and contradict this, *O. adeonae* having a progressive reduction in size from P_1 to P_3. That species is also known from tropical Australia and for some time A. H. Clark regarded *anisa* as a synonym of it, although by 1947 he had given way to H. L. Clark's insistence that the proportions of the proximal pinnules serve to distinguish it. I think the relationships between these nominal species would repay further study.

Oligometra serripinna (P. H. Carpenter)

Antedon serripinna P. H. Carpenter, 1881: 175, 182.

Oligometra serripinna.—A. H. Clark, 1918: 130–131; 1947: 216–217.

(?) *Oligometra serripinna.*—H. L. Clark, 1946: 49–50.

Material

Station 6, 2 specimens.

H. L. Clark (1946) includes this species in the Australian fauna on the strength of a single rather dubious record from the Abrolhos of which I can trace no mention by A. H. Clark in 1947. Other Australian records of *O. serripinna* have all been referred to other species, especially *O. carpenteri*, and the nearest locality for *O. serripinna* given by A. H. Clark (1947) is New Guinea. The present record therefore adds another species to the echinoderm fauna list for Queensland, if not for Australia. Although *Oligometra* is notoriously variable in the form of the proximal pinnules so that a number of subspecies of *O. serripinna* have been recognized, the present two specimens with their very rugose but

relatively slender pinnules contrast so strongly with the extremely stout sharply prismatic and elaborately-finned pinnules (especially P_2) of the other five specimens of *Oligometra* from the same station, which I am calling *O. carpenteri,* that I cannot regard them as conspecific.

One of the two specimens is very small but the other has arm length c. 35 mm and br at the first syzygy (3 + 4) 1.05 mm. It has c. VIII mature cirri plus c. V more or less immature ones, the former having up to 22 segments, none of them longer than wide. P_1, P_2 and P_3 have respectively 14, 15 and 12 segments and are 3.1 mm, 4.75 mm and 2.65 mm on one arm studied.

Oligometra carpenteri (Bell)

Antedon carpenteri Bell, 1884: 157, pl. 10, fig. A.

Oligometra carpenteri.—A. H. Clark, 1911b: 775–776.—H. L. Clark, 1932: 202; 1946: 49.

Material

Station 6, 5 specimens.

Even the largest specimen has the arm length only c. 25 mm and br at the first syzygy (3 + 4) c. 0.75 mm. There are no more than 14 cirrus segments and the relatively huge P_2 has 13 segments.

In the holotype of *O. carpenteri,* which is in the British Museum collections and came from Port Curtis, the arm length was c. 50 mm. Br at the first syzygy is 1.5 mm and there are up to 20 cirrus segments.

Colour notes from life of three of the Swain Reefs specimens are "cream and deep purple", "ribs deep red remainder cream" and "ribs dark red remainder creamish yellow".

PTILOMETRIDAE

Ptilometra australis (Wilton)

Encrinus australis Wilton, 1843: 118–120.

Ptilometra mülleri A. H. Clark, 1909b: 41.—H. L. Clark, 1916: 24.

Ptilometra australis. H. L. Clark, 1946: 55–56.—A. H. Clark, 1947: 403–415, fig. 207.

Material

Station 6, 1 badly broken specimen.

This record extends the range of the species northwards from off the mouth of the Clarence River, northern N.S.W., though there is a specimen in the British Museum collections taken near Southport, S. Queensland in 45–50 metres and sent by Dr Sutherland of the University of Queensland.

The cirri of the Swain Reefs specimen number only X, being arranged in a single row around the discoidal centrodorsal. The longer cirri have 46 or 47 segments, all much shorter than broad; there is a tendency for a triple keel to

develop on the dorsal side of the distal segments. There is a syzygy in the IBr series. The IIBr series are usually (perhaps always) of four ossicles; most are broken. The first arm syzygy is at 2 + 3 on arms based on IIBr series. PD has 20 segments and is small compared with the basal pinnules of the arms, which have about 12 segments, these being relatively elongated after the first two.

There are also three specimens in the present collection from 13 miles off the Clarence River mouth in N.S.W., which show various degrees of compromise between the characters given in the keys of H. L. Clark (1946) and A. H. Clark (1947) to *P. macronema* and *australis*. The latter key reads as follows:

Macronema:

a^1 Proximal cirrus segments as long as, or longer than, broad; cirrus sockets in more or less definite columns, three to each radial area; middle segments of the proximal pinnules half again to twice as long as broad; distal pinnules with the third and following segments longer than broad.

Australis:

a^2 Proximal cirrus segments about twice as broad as long, or at least broader than long; cirrus sockets usually irregularly arranged; middle segments of the proximal pinnules not so long as broad; distal pinnules with the segments broader than long until the distal third.

Although in these three specimens the proximal cirrus segments are distinctly broader than long, agreeing with *australis,* the cirrus sockets are in more or less regular columns, there being four in each radial area in one specimen at least and the middle segments of the pinnules are longer than broad, as in *macronema*. A rather more precise study of variation in *Ptilometra* is needed.

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The External Features of the Heads of Leafhoppers

(Homoptera, Cicadelloidea)[1]

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Figures 1–65

[1] For the purpose of this study, the Membracidae, and related families (Aetalionidae, Nicomiidae, Biturritidae) which have been grouped together by Strümpel (1972) into the superfamily Membracoidea, are here included in the Cicadelloidea.

CONTENTS

SUMMARY

The external features of the heads of insects comprised in the superfamily Cicadelloidea are described and they are shown to be extremely unstable in comparison with those of insects in the other superfamilies of the Auchenorrhyncha.

By using a series of weighted characters an attempt is made to assess the evolutionary levels, and periods of geological origin, of the species selected for illustration. Possible homologies of the sclerites, sutures, and clefts, of the heads of leafhoppers are discussed.

1. INTRODUCTION

The heads of adult insects comprised in a single family or superfamily are usually stabilized at approximately the same level of evolutionary development and, moreover, resemble each other in general appearance. For this reason, insect groups, to which neither of these generalizations apply, are of unusual interest.

Outstanding, and possibly pre-eminent amongst such groups, is the superfamily Cicadelloidea. It is the purpose of this paper to draw attention to this phenomenon in leafhopper heads and to discuss its varied significance.

A claim that cicadelloid heads may differ more from each other in general appearance than do insects comprised in other superfamilies would, by itself, be impossible to substantiate. Thus, for example, the heads of insects in a related superfamily, the Fulgoroidea, are even more diverse in appearance. The differences, however, which separate fulgoroid heads from each other are essentially of a superficial nature unlike those between the heads of many of the Cicadelloidea. Some of the latter differ from others so considerably that heads of insects of presumed Mesozoic origin can be readily distinguished from others of more recent development, and differences may exist between the heads of species belonging to a single genus of a greater magnitude than the ones separating from each other the heads either of all the Cercopoidea or of all the Cicadoidea.

For purposes of comparison with the Cicadelloidea the basic structural characteristics of the heads of insects comprised in each of the three other superfamilies of the Auchenorrhyncha need to be noted.

2. HEAD CHARACTERISTICS OF THE FULGOROIDEA, CERCOPOIDEA AND CICADOIDEA

Fulgoroidea

The transclypeal suture is incomplete. The lora are *always* laterally associated with the postclypeus for its entire length. The maxillary plates are *always* narrow and largely concealed. The epistomal suture is *always* retained and facially situated, and subgenal sutures are sometimes present. The tentorium is complete but the anterior arms are weakly developed and their pits are difficult to locate. Except in the Tettigometridae, the paired ocelli are *always* close to the antennal bases and a median ocellus is occasionally retained. The frons is *always* separately defined and ventrally situated. The antennae, which arise from ring-like structures, are situated either in front of the eyes, or adjacent to their anterior margins.

Cercopoidea

The transclypeal suture is *always* complete. The lora lie alongside the postclypeus for approximately the same length of the latter in *all* species. The narrow maxillary plates are *always* largely concealed. The epistomal suture is *always* present and is situated on the crown of the head. There is seldom any trace of subgenal sutures. The tentorium is complete and the pits of the anterior arms are adjacent to the antennal bases. The paired ocelli are *always* on the crown. The frons is likewise *always* on the crown and *always* rectangular in shape. The antennae are situated under overhanging marginal ledges which are *always* in approximate alignment with the transverse epistomal suture.

Cicadoidea

The transclypeal suture is *always* complete and well defined. The lora, which lie alongside the greater part of the sides of the postclypeus, *always* terminate posteriorly adjacent to the antennae. The maxillary plates are *always* narrow and largely concealed. The epistomal suture is *always* present and there is little, if any, trace of subgenal sutures. The tentorium is complete and the pits of the anterior arms are adjacent to the antennal bases. The paired ocelli are *always* on the crown. The frons, which is *always* triangular in shape and bears a median ocellus, is likewise *always* on the crown. The many-segmented antennae are situated under overhanging ledges which are *always* in approximate alignment with the epistomal suture.

If, from among the characteristics listed above, primitive ones are separated from those of a secondary nature, the situation is as follows:

Primitive Head Characteristics

Fulgoroidea

An incomplete transclypeal suture; the lateral association of the lora with the entire length of the postclypeus; narrow, and largely concealed, maxillary plates; a ventral epistomal suture; the occasional retention of subgenal sutures; a complete tentorium; ventrally situated ocelli; the occasional retention of a median ocellus; a completely defined, ventrally situated, frons; anteriorly situated antennae, approximately in alignment with the epistomal suture.

Cercopoidea

Narrow maxillary plates, which may be completely concealed; a well-defined epistomal suture; a complete tentorium; a distinct frons; antennae in approximate alignment with the epistomal suture.

Cicadoidea

Lora which are laterally associated with the postclypeus for the greater part of its length; largely concealed maxillary plates; an epistomal suture; a separate, though reduced, frons; a complete tentorium; a median ocellus; segmented antennae in approximate alignment with the epistomal suture.

Secondarily-acquired Head Characteristics

Fulgoroidea

Highly specialized antennae with unsegmented flagellae.

Cercopoidea

A complete transclypeal suture; a dorsal epistomal suture; infrequently retained subgenal sutures; dorsal ocelli; a dorsal frons; posteriorly situated antennae.

Cicadoidea

A complete transclypeal suture; a dorsal, or marginal, epistomal suture; subgenal sutures lacking; dorsal ocelli; a dorsal frons; posteriorly situated antennae.

The aspect of the head characteristics of these three superfamilies, which it is particularly desired to emphasize, is their almost complete stability. The situation which obtains in the Cicadelloidea, and which is described below, is a very different one.

3. HEAD CHARACTERISTICS OF THE CICADELLOIDEA

The transclypeal suture *may* be complete or incomplete. The lora *may* terminate posteriorly close to the antennal bases or be widely separated from them. The maxillary plates *may* be entirely concealed, and if exposed, then either wide or narrow; the epistomal suture *may* be retained and either facially, or marginally, situated. Subgenal sutures *may* be present. The short anterior arms of the tentorium lack association with the posterior arms and they *may* be branched or simple. The pits of the anterior arms are adjacent to the antennal bases. The paired ocelli *may* be on the face of the head, or on the crown, marginally situated, or lacking. The frons, which *may* be separately differentiated, or continuous with the postclypeus, *may* be on the face, or on the crown of the head. The antennae, which *may* be short, or long, *may* be anteriorly, or posteriorly situated and supra-antennal ledges *may* be present or absent.

The numbers in the right hand column of the tables which follow, represent the extent to which leafhopper head characteristics are here regarded as primitive (P), or secondary (S). The reason weighting has been given to some primitive, but to no secondary characters, is that it is assumed that some of the former, though possibly none of the latter, may be of greater significance than others.

While it has been a simple matter to select characteristics for inclusion in the first table, and, in fact, it has been unnecessary to use all those available (such as the position of the base of the antennal ledges in relation to the eyes), it has not been so easy to choose characters for the second one. Moreover, in order to avoid obscuring a picture which is otherwise reasonably clear, certain frequently occurring types of head development have needed to be omitted.

Table 1

Primitive head characteristics of Cicadelloidea

		P
1	Posterior apices of lora, hence the point of attachment of the mandibular levers to the cranium, close to the ATP's and the antennal bases	4
2	Subgenal sutures well, or moderately, developed	3
3	An entirely ventral frons enclosed by well, or obscurely, defined postfrontal and epistomal sutures	
	or	
4	A transverse, or slightly arched, epistomal suture, which may be obscure, situated on the face of the head, more or less between the antennal ledges	2
	or	
5	The frons, or frontoclypeus, situated entirely on the face of the head, but the former not separately defined	
6	Ventral ocelli, not closely adjacent to the hind margin of the face	1
7	Transverse, or approximately transverse, antennal ledges	1
	Possible Total	14

Table 2

Secondarily-acquired head characteristics of Cicadelloidea

		S
1	Posterior apices of lora widely separated from the ATP's and antennal bases	2
2	Subgenal sutures lacking	2
3	An entirely dorsal, well defined, frons	2
	or	
4	An entirely dorsal frons, not separated anteriorly from the postclypeus	2
	or	
5	An entirely dorsal frons, not completely separated from the vertex	2
6	Marginal or dorsal ocelli, or ocelli lacking	2
7	Postfrontal suture entirely lacking	2
8	Strongly arched, steeply oblique, or no, antennal ledges	2
9	Anteclypeus completely separated from the postclypeus by a transverse suture	2
	Possible Total	14

4. DISCUSSION OF INSECT HEADS ILLUSTRATED

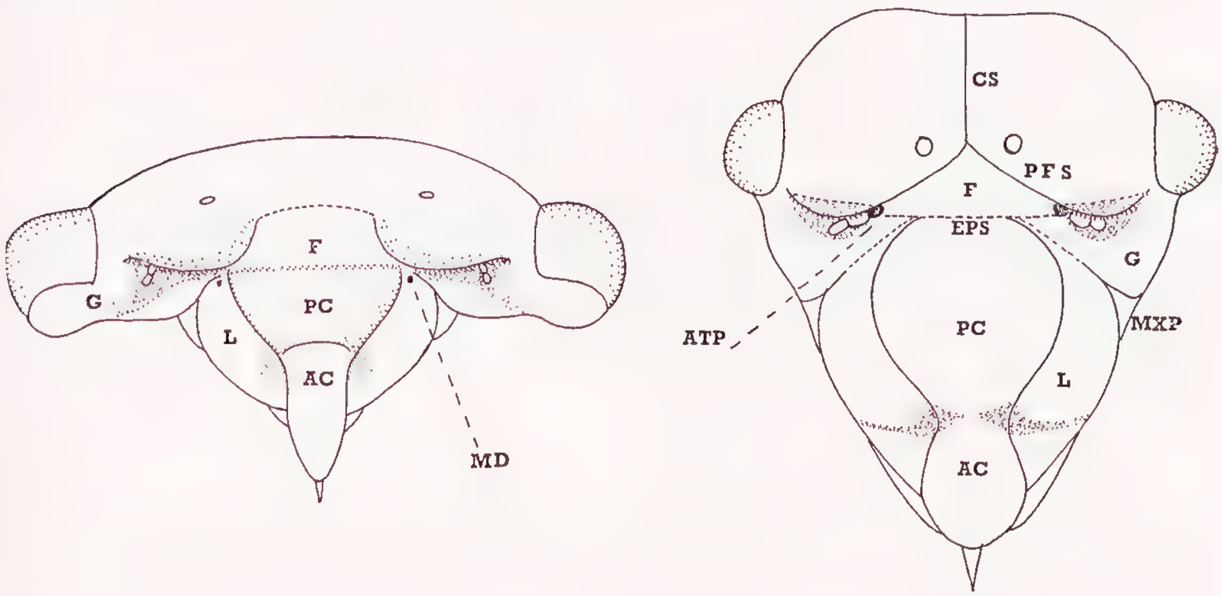
Figs 1 and 2 represent leafhopper heads with more primitive characteristics than those of any others illustrated.

Figure 1. *Coloborrhis reticulata* Evans (P 13: S 2)

The genus *Coloborrhis* Germar contains 17 described species. The type species, *C. corticina* Germar, is of widespread distribution in Africa. It occurs also in Madagascar, to which island the remaining 16 species are confined. These differ very considerably from each other in external features and it has been suggested their speciation may have been of an "explosive" nature, (Evans, 1959). Some indication of the extent of the differences separating *Coloborrhis* spp. may be obtained by comparing fig. 1 with figs 36 and 37. The two latter represent the head of *C. ledroides* Evans in facial and dorsal aspects.

While differing from the heads of other species comprised in the same genus, the head of *C. reticulata* resembles those of some membracids. This may be appreciated by comparing fig. 1 with fig. 4 (*Holdgatiella chepuensis* Evans). It resembles even more closely the head of the nicomiid, *Nicomia cicadoides* Walker, illustrated in Evans, 1948 (fig. 4).

At one time the genus *Coloborrhis* was included in the Membracidae (Funkhouser, 1950). Its present inclusion in the cicadellid subfamily, the Ulopinae, is, however, probably correct and the genus can be regarded as one of a complex of relict Mesozoic genera possessing both cicadelloid and membracoid affinities.



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Its membracoid affinities are further emphasized by the fact that several species in the genus (*C. cristata,* Ev., *C. cornuta* Ev. and *C. monstrosa* Ev.) have enlarged pronota. In respect to its presumed antiquity, it is of interest to note that in common with *Nicomia cicadoides,* some species (*C. enigma* Ev., *C. rugosa* Ev. and *C. planata* Ev.) have retained a venational characteristic of infrequent occurrence in the tegmina of present day leafhoppers but usual in Palaeozoic and Mesozoic forms. This is the presence of an acute proximal bend in vein CuA.

Although the head of *C. reticulata* retains an unusually large number of primitive features and some other species in the genus have, as well, both primitive tegminal and abdominal characteristics, this cannot necessarily be taken as an indication that these insects are actual Mesozoic relicts as their specific differentiation may well have taken place subsequent to the isolation of Madagascar, which may date from Tertiary times. It is for this reason that no entry has been made in the last column of the appendix in respect to this species.

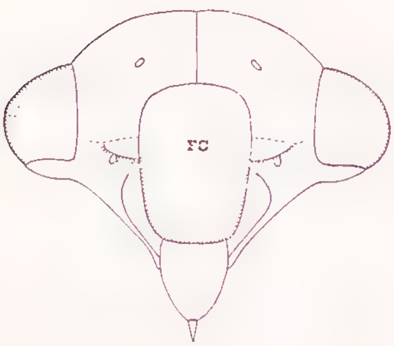
Figure 2. *Darthula hardwickii* Gray (P 14: S 0)

The monotypic genus *Darthula* Gray is the sole genus in the Darthulinae, one of the two subfamilies of the Aetalionidae. *D. hardwickii* is the largest of all extant leafhoppers, having a length of 30 mm. Part of this length consists of an apical sword-like extension of the 9th abdominal tergum, common to both sexes. Previously I have suggested this process might be homologous with the similar one of the Lower Permian archescytinid, *Permoscytina kansasensis* Carpenter (Evans, 1957). Bekker-Migdisova, however, has shown that the Archescytinidae are ancestral to the Aphidoidea, hence do not lie on the same line of descent as the Auchenorrhyncha (Bekker-Migdisova, 1960).

Although the Aetalionidae are one of the families of the Membracoidea, as defined by Strümpel (1972), their heads differ in proportions from those of most of the Membracidae, being longer than wide, rather than, as is usual in membracids, wider than long. In this they resemble the biturritid, *Tropidaspis carinata* (Fabricius) (fig. 5) which, likewise, is of membracoid stock.

In having a score of fourteen for primitive features and zero for specialized ones, the head of *D. hardwickii* can be regarded, not only as more primitive in external features than those of any other known cicadelloid, but also, possibly, as more primitive than the heads of any other living Auchenorrhyncha.

Figs 3, 4 and 5 illustrate the heads of three membracoids, two of them belonging to the Biturritidae (figs 3 and 5) and one (fig. 4) to the Membracidae.



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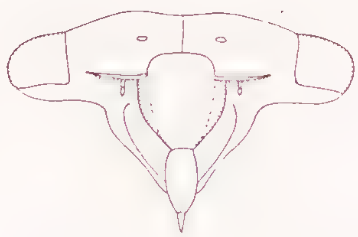

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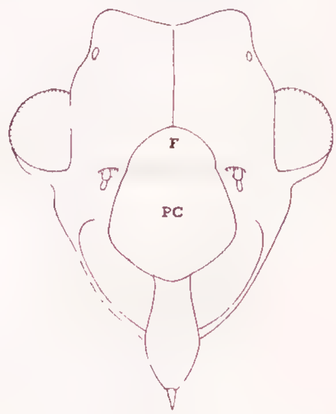

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Figure 3. *Melizoderes darwini* Funkhouser (P 9: S 4)

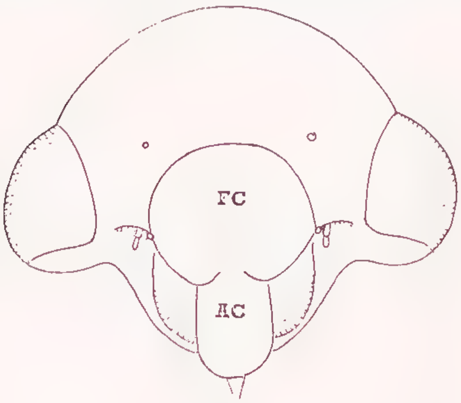
This head has been selected for illustration to re-emphasize the close resemblance that may exist between the heads of representatives of the Cicadelloidea and of the Membracoidea.

Figure 4. *Holdgatiella chepuensis* Evans (P 9: S 4)

While *H. chepuensis* cannot be regarded as a typical membracid, since its pronotum is of normal proportions, undoubtedly it belongs to this family. This head can be regarded as representing the generalized head-type of the family as a whole.

Figure 5. *Tropidaspis carinata* (Fabricius) (P 3: S 9)

Although the head of this biturritid retains a fairly distinct frons and in proportions resembles the heads of aetalionids, rather than those of membracids, it, nevertheless, is highly specialized. In its particular specializations it resembles the head of *Endoiastus productus* Osborn (illustrated in Evans, 1948, fig. 5B), which likewise, has been attributed to the Biturritidae. A consideration of the proportions and characteristics of the heads illustrated in figs 1–5 inclusive suggests the possibility that the family Biturritidae may be a composite one made up of ulopine (figs 1, 3, 4) and aetalionid (figs 2, 5) derivatives.



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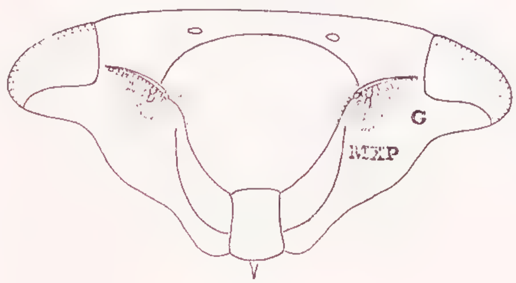

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Heads of insects comprised in the Macropsinae and Jassinae are illustrated in figs 6 and 7. Because of certain shared characteristics, in particular the position of the ocelli, *Macropsis* Lewis and *Jassus* Fabricius were at one time assigned to the same subfamily grouping. Both heads retain numerous generalized characteristics, but in having an incomplete transclypeal suture and narrow maxillary plates, that of *Stenopsoides turneri* may be regarded as the more primitive.

Figure 6. *Stenopsoides turneri* Evans (P 10: S 2)

While no trace of a separate frons is evident in the head illustrated, one can be discerned in that of another species in the same subfamily, *Stenoscopus drummondi* Evans, which, likewise, is confined to southwest Australia. The latter has been figured previously and its general resemblance to the head of a biturritid, *Melizoderes* sp., noted (Evans, 1971). *S. turneri* has an enormously enlarged pronotum which serves to support the supposed affinity of the Macropsinae to the Membracidae.

Figure 7. *Jassulus brunneus* Evans (P 9: S 4)

Unlike the heads of the Macropsinae those of representatives of the Jassinae are very varied in shape, proportions and ocelli position. The head of *J. brunneus* has been chosen for illustration as representing the most generalized head-type known in this subfamily.

Figs 8–13, inclusive, illustrate the heads of leafhoppers belonging to the tribe Ulopini. These display an unusual assemblage of primitive and specialized features. Among the former are the retention of a ventral frons and the possession of more complete subgenal sutures than occur in the heads of cicadellids belonging to any other groups. Specialized characters include the dorsal position of the ocelli and the wide separation of the posterior corners of the lora from the inner apices of the antennal ledges.

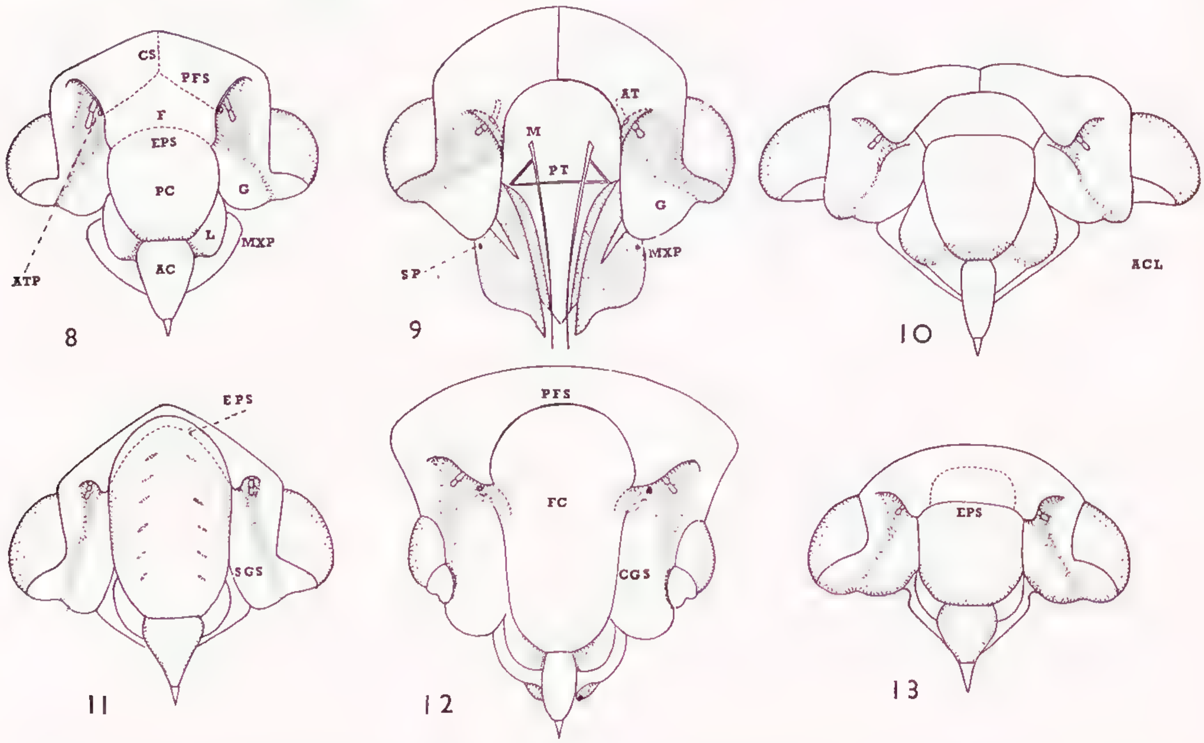


Figure 8. *Woodella wanungarae* Evans (P 7: S 8)

Even although more specialized, than primitive, characters are recorded for this head, it is nevertheless the most generalized one known within the Ulopinae. The nature and extent of its specializations can best be appreciated by comparing fig 8 with figs 1 and 2.

Figure 9. *Austrolopa brunensis* Evans (P 7: S 8)

The head illustrated, from which the frons and clypeus have been removed, resembles that of *W. wanungarae* (Fig. 8) in general features. It differs in the broader association of the maxillary plates with the cranium and in having the postclypeus, anteriorly, forming a lip-like structure which overhangs the anteclypeus. A somewhat similar, though less pronounced, development occurs also in the heads of some eurymelids. In the Ulopini the sensory process on the maxillary plate, which I have suggested may represent a reduced and modified maxillary palp (Evans, 1973) is always at the base of the maxillary plate.

Figure 10. *Moonia variabilis* Distant (P 8: S 5)

The head of *M. variabilis* bears a close resemblance, both in structure and proportions, to that of *Coloborrhis reticulata* (fig. 1). The principal differences are of ocelli position and the separation of the loral bases from the antennae and the tentorial pits. As has been mentioned previously *Coloborrhis* and *Moonia* Distant are the sole genera of the Ulopini to be known only in the fully-winged form (Evans, 1971b).

Figure 11. *Taslopa montana* Evans (P 6: S 6)

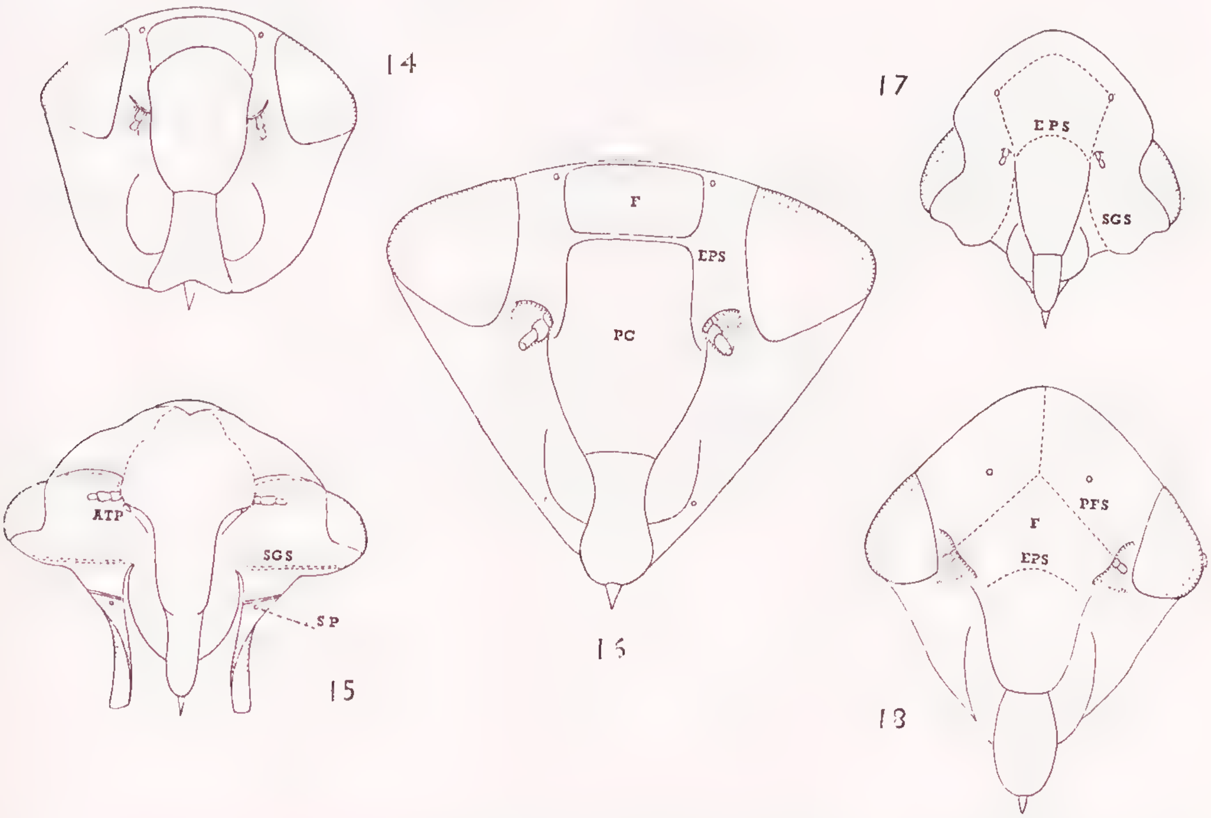
In this head the postclypeus has encroached so far on to the frontal area as to result in the epistomal and postfrontal sutures almost coinciding. There is also an extensive development of the clypeogenal sulcus.

Figure 12. *Megulopa sahlbergorum* Lindberg (P 6: S 6)

This is the most specialized of all known ulopine heads, not solely on account of its shape and proportions, but also because of the very wide separation of the points of attachment of the mandibular levers from the anterior tentorial pits; the lack of a transverse epistomal suture, and the long clypeogenal sulcus.

Figure 13. *Novolopa townsendi* Evans (P 6: S 6)

While in the head of *Taslopa montana* (fig. 11) the postfrontal suture is the most prominent posterior cephalic suture, in this head the epistomal suture is the one most strongly developed.



Figs 14–15 illustrate heads in which a distinct and separate frons is retained.

Figure 14. *Caelidoides tristis* Signoret (P 4: S 6)

This insect is one of several which have been referred to the Coelidiinae but are of uncertain relationships. As well as being unusual in retaining a distinct frons, this head is remarkable for the size of the maxillary plates, which are continuous with the extensive genae.

Figure 15. *Khyphocotis tessellata* Kirkaldy (P 8: S 2)

Although an epistomal suture is lacking, the extent of the frons is clearly evident. An unusual feature is the occurrence of a transverse line of strengthening on the maxillary plates anterior to the subgenal sutures and adjacent to the sensory processes. Such a line, which is present also on the head of *Nicomia cicadoides,* might possibly represent the margin of the stipes.

Figure 16. *Tartessus* sp. (nymph) (P 4: S 7)

In the heads of the nymphs of some species of *Tartessus* Stål the frons is better defined as a distinct sclerite than in the heads of any other known cicadelloids.

Figure 17. *Koebelia californica* Baker (P 8: S 6)

This is one of the few species of relict leafhoppers which has retained a food plant association with a gymnosperm. The extensive genal area is a further development of the condition found in the heads of ulopines (e.g. fig. 9).

Figure 18. *Agalliana pauliana* Evans (P 5: S 8)

This head retains more primitive characteristics than is suggested by its rating, in particular in respect to the shape of the postfrontal suture and the size of the lora in relation to the postclypeus.

Figs 19–21 lack particular association with each other but display individual points of interest.

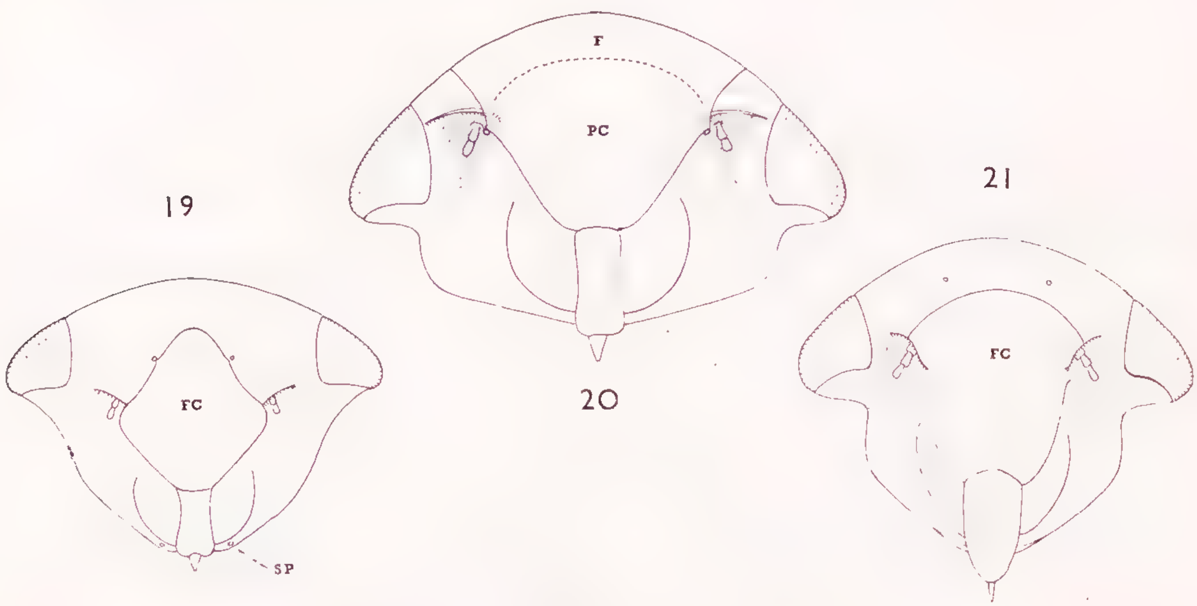


Figure 19. *Opio multistrigia* (Walker) (P 5: S 5)

Apart from a few species, which have an anterior lip-like enlargement of the frontoclypeus, and one, which has horn-like extensions on the head (*Cornutipo tricornis,* fig. 57), the heads of eurymelids are extremely stable. The frontoclypeus is always diamond-shaped; the ocelli are always close to the postfrontal suture; the maxillary plates are always wide and the sensory pits are always anteriorly placed.

Figure 20. *Eryapus gibbus* Evans (P 3: S 10)

The head of *E. gibbus* which is unusually wide and has extensive maxillary plates, differs from those on either side of it in retaining an obscure epistomal suture; in the frons extending onto the crown of the head and in the ocelli being marginally situated. It differs from the head of *O. multistrigia* (fig. 19) also in the presence of an acute ante-ocular emargination. This, presumably, marks the separation of the genae from the maxillary plates, although a similar curve in the heads of some leafhoppers appears to be associated with the retreat of the antennae from a former, more anteriorly situated, position (*see* figs 29, 50).

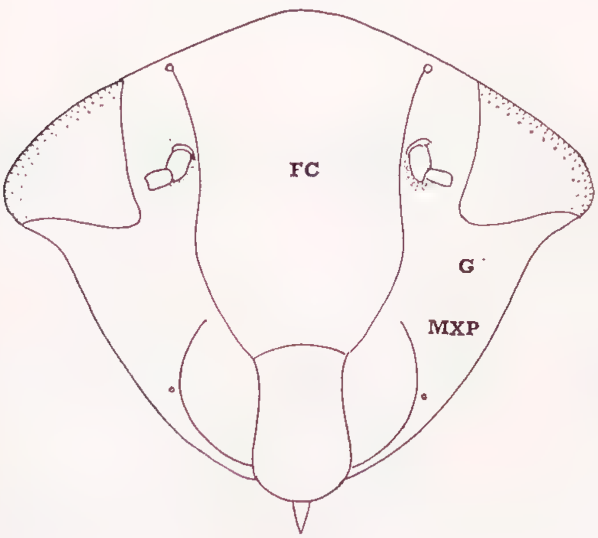
Figure 21. *Tiaja* sp. (P 4: S 8)

Uncertainty exists as to the relationships of the Megophthalmini. Thus, Oman (1949), and Wagner (1951), have associated them with the Agalliinae, while I, for reasons given previously, prefer to regard them as a tribe of the Ulopinae, though acknowledging their affinity with the former subfamily (Evans, 1947, 1968). Their heads are of special interest since the ocelli are either facially situated, as shown in fig. 21, or else lie in marginal depressions, hence are more primitively situated than those of any other ulopids, all of which have dorsal, or no, ocelli.

The heads illustrated in figs 22–24 are representatives of the Deltocephalinae and Cicadellinae. These are the dominant leafhopper subfamilies at the present time.

Figure 22. *Idiodonus cockerelli* (Ball) (P 2: S 12)

The Deltocephalinae, which are of worldwide distribution, are by far the most abundant of all cicadellid subfamilies. With the exception of the Platymetopiini, and some aberrant genera, their heads lack specialized features but have lost many of a primitive nature. The extent of this loss will be appreciated if fig. 22 is compared with fig. 1. Thus, in the head of *I. cockerelli* the lora,



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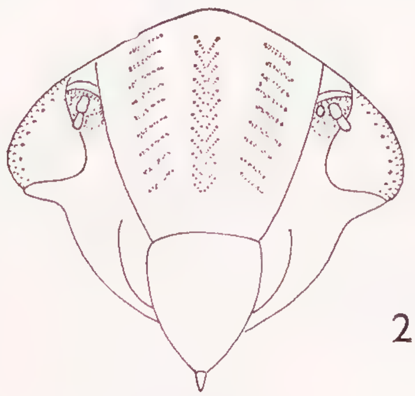

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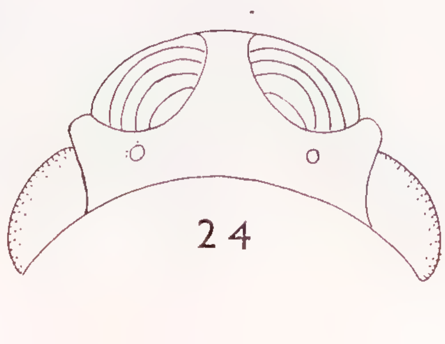

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posteriorly, lie at a considerable distance from the antannae; the maxillary plates, which are wide and exposed, are continuous with the genae; supra-antennal ledges are lacking, likewise the epistomal suture and the hind margin of the postfrontal suture, and the ocelli are marginally situated.

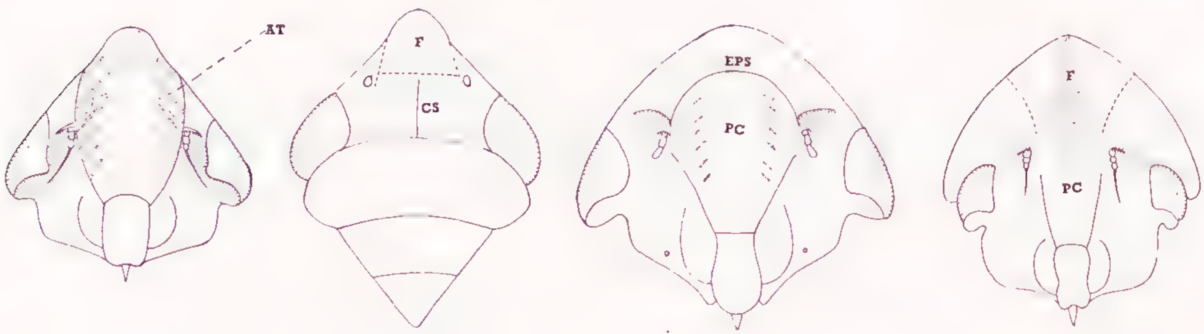
Figures 23, 24. *Cicadella spectra* (Distant) (P 1: S 12)

The Cicadellinae are essentially insects of the tropics and subtropics but also occur sparingly in cool temperate regions. The most notable features of their heads are the encroachment of the cibarial muscles onto the frontal region and their extension onto the crown of the head. Also to be noted is the position of the antennal ledges adjacent to the hind margin of the face, and the dorsal position of the ocelli.

In the group of heads illustrated in figs 25–28 the frons, or frontoclypeus, extends onto the crown of the head and the ocelli are either marginally, or dorsally, situated.

Figures 25, 26. *Chiasmus varicolor* (Kirkaldy) (P 1: S 10)

Formerly this species, which is of widespread distribution in the warmer parts of the world, was known as *Kosmiopelix varicolor* and was regarded as belonging to the tribe Aphrodini of the subfamily Aphrodinae (Evans, 1966). Recently it has been transferred to the genus *Chiasmus* Mulsant and Rey (Evans, 1974) and Ribaut's assignment of this genus to the Deltocephalinae accepted (Ribaut, 1952). The heads illustrated in figs 25 and 23 provide two different examples of the effect of the backward migration of the cibarial muscles on the shape, position and extent, of the postclypeus.



25 26 27 28

Figure 27. *Hecalus afzelii* (Stål) (P3: S 10)

In this head, in which the epistomal, but not the postfrontal suture, is retained, the frontal region is not separately defined and the ocelli are marginal in position.

Figure 28. *Eupelix cuspidata* (Fabricius) (P 0: S 12)

This highly specialized head, which also has marginal ocelli, differs from that of *H. afzelii* in the loss of the epistomal suture and in having the frons faintly defined. Unusual features are the extension of the vertex around part of the sides of the eyes and very extensive maxillary plates.

Although the heads illustrated in figs 29–31 are of insects belonging to different subfamilies they share in common an unusual feature, the occurrence of the ocelli on marginal rims separating the face from the crown of the head.

Figure 29. *Selenomorphus nigrovenatus* Evans (P 4: S 10)

While lacking a venational characteristic common to all other tribes of the Jassinae (the apical fusion, in the hind wings, of veins Rs and M1+2) the Selenomorphini are almost certainly correctly regarded as belonging to this subfamily (Evans, 1974). The head of *S. nigrovenatus* is more generalized than the two adjacent ones, since the antennal ledges are close to the anterior margins of the eyes and the postfrontal suture lies at a considerable distance from the hind margin of the face.

Figure 30. *Drabescus heroni* Evans (P 3: S 8)

This head closely resembles the adjacent one to the right (fig. 31) and for this reason at one time I regarded the genus *Drabescus* Stål as a component of the Selenocephalini (Evans, 1947) and not, as is now accepted, meriting separate subfamily status. Differences to be noted between the two heads are the position of the ocelli in relation to the eyes, and of the postfrontal sutures, laterally, in relation to the antennal ledges.

Figure 31. *Selenocephalus* sp. (P 3: S 8)

This figure requires no separate discussion.

Sexual dimorphism, apart from differences in the size of the sexes is of infrequent occurrence in the Cicadelloidea. In the heads of the two species illustrated in figs 32–35 the frons is narrowly produced in female, but not in male, insects.

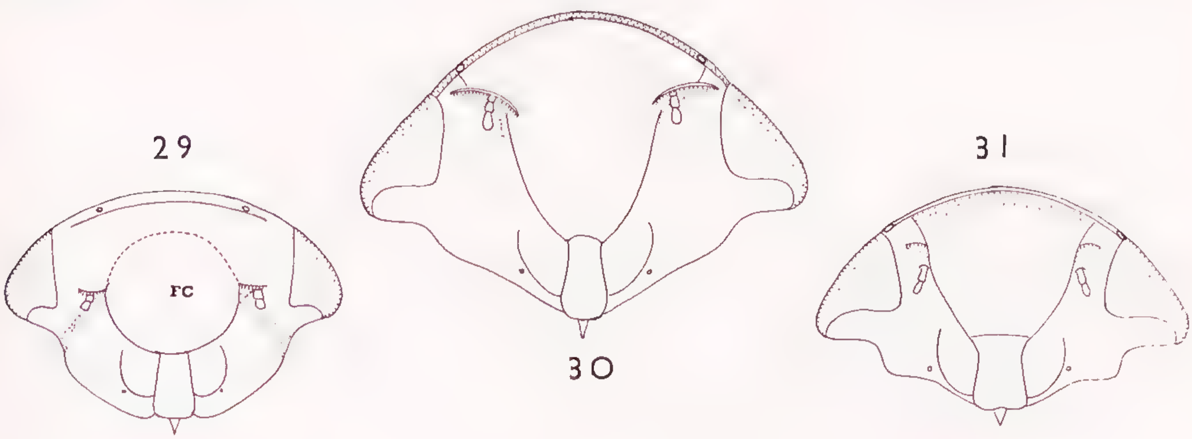


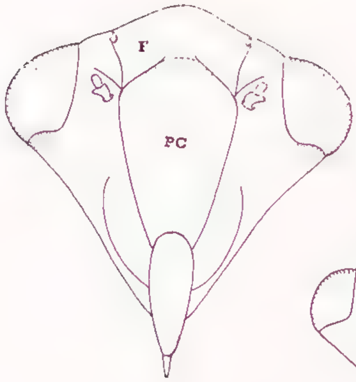
Figure 32, ♂, *Figure* 33, ♀, *Tartessoides griseus* Evans (P 3: S 8)

It needs to be noted, although the frons is retained as a separate sclerite in these heads, that the P rating is a low one.

Figure 34, ♀, *Figure* 35, ♂, *Stenotartessus mullensis* (Evans) (P 3: S 8)

Although having the same rating as *T. griseus* this pair of heads is even more specialized, since the antennal ledges lie posterior to the eyes and the frontal region is enormously enlarged.

The heads illustrated in figs 36–45, like those in figs 29–31, provide an example of parallel evolution, for they are of insects belonging to five separate subfamilies.



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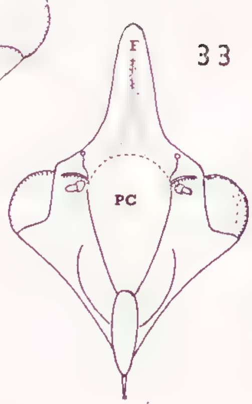

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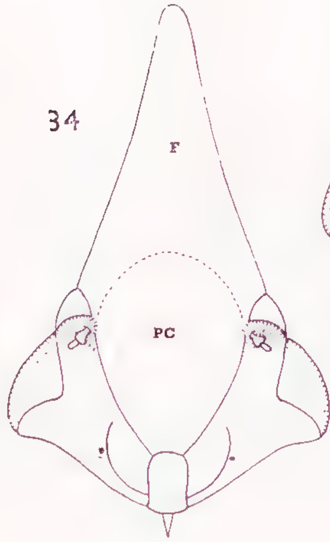

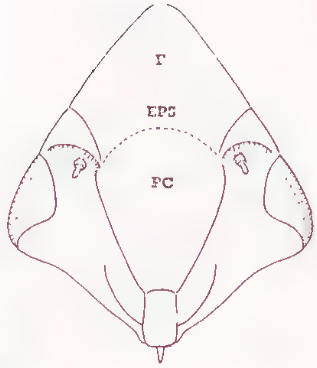

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Figures 36, 37. *Coloborrhis ledroides* Evans (P 4: S 6)

Fig. 36 should be compared with fig. 1, which illustrates the head of an insect ascribed to the same genus. Apart from shape, the principal differences which separate these two heads, are associated with an increase, in the head of *C. ledroides,* of the postclypeus and genae. It will be noted in both heads, that the lora retain the same position in relation to the eyes, while the genae, in fig. 36, are considerably enlarged.

Figures 38, 43. *Platyscopus badius* Evans (P 3: S 10)

The frons is not separately defined and the backward extension of the postclypeus is, in part, associated with head lengthening.

Figure 39. *Mapochiella collaris* Distant (P 0: S 12)

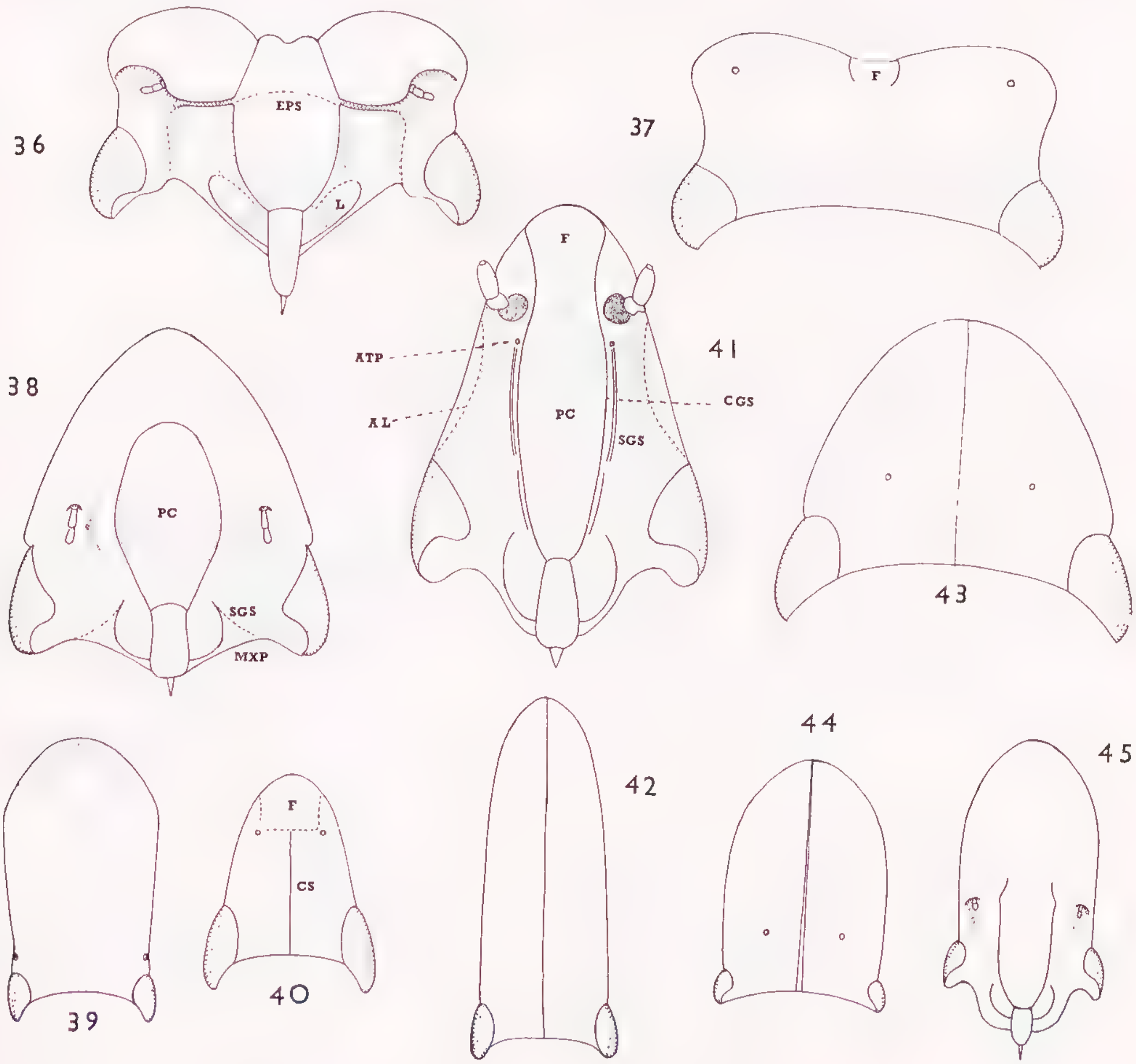
Most Paradorydiini have heads which taper apically (*see* fig. 49) but a few occurring in India, Africa and Australia, have spatulate heads. The ocelli are more marginally situated than truly on the crown but, as in the adjacent head (fig. 40), they have retained their primitive position close to the sides of the postfrontal suture.

Figures 40, 41. *Occinirvana eborea* Evans (P 0: S 8)

As in the head of *C. ledroides* (fig. 37), the frons in this species is, in part, on the crown but, while in *O. eborea* the ocelli have retained their primitive situation, they have not in the head of *C. ledroides.* Because of the backward extension of the head, as viewed facially, the antennae have become posteriorly situated and, moreover, the antennal ledges have come to margin the sides of the face. It is tentatively suggested that the pair of narrow channels on either side of the postclypeus, which terminate posteriorly at the anterior tentorial pits, may represent the subgenal sutures and, in support of this suggestion, fig. 41 should be compared with fig. 11.

Figure 42. *Dorycephalus hunnorum* Emeljanov (P 2: S 10)

I have not been able to distinguish the ocelli on this head but, if retained, they will be situated in a position similar to those of *M. collaris* (fig. 39) and not, as in the Ledrini, which they so closely resemble, where they are on the disc of the crown.



Figures 44, 45. *Ledropsis crocina* Distant (P 3: S 8)

The crown of this head, as well as being similar in general appearance to those illustrated in figs 38, 40, 42 and 43 bears a particularly close appearance to that of *P. badius* (fig. 43), since in both heads the ocelli are similarly situated. The Ledrini and the Penthimiinae, nevertheless, are not closely related groups and in the former, which have been derived from the Ulopini, dorsal ocelli are an ancient feature, while in the Penthimiinae, most of which do not have spatulate heads, they represent a more recent evolutionary development.

Although many salient primitive characters are lacking in the heads of some ledrids, in others, traces of the epistomal suture, subgenal sutures, and a separate frons, are retained.

The heads illustrated in figs 46–49 provide a further example of parallel evolution occurring in two widely separated groups of leafhoppers. In both, series can be traced from forms with short, to others with very long, heads. Climax forms in both the Cephalelini and the Paradorydiini are similar in size, shape and general appearance. It is of interest to note that while short headed Cephalelini occur in Australia they have never been recorded from either South Africa or New Zealand. This suggests the possibility that the original derivation of the Cephalelini from a ulopine stock may have taken place within the Australian component of Gondwanaland.

Figure 46. *Cephalelus bulbosa Evans* (P. 3: S 8)

Although this is one of the climax forms of the Cephalelini, the head still retains an ancient feature in the form of subgenal sutures.

Figure 47. *Cephalelus minutus* (Evans) (P 3: S 8)

This represents the head of a "basic" representative of the Cephalelini.

Figure 48. *Cephalus ianthe* (Kirkaldy) (P 3: S 8)

In this intermediate form, in which the subgenal sutures are obscure, the association of the subocular emargination with the point of junction of the genae and the maxillary plates can be recognized. This enables an interpretation to be made of the similar emargination in the adjacent head of *P. menalaus* (fig. 49), in which, unlike the head of *C. ianthe,* the maxillary plates are extremely wide.

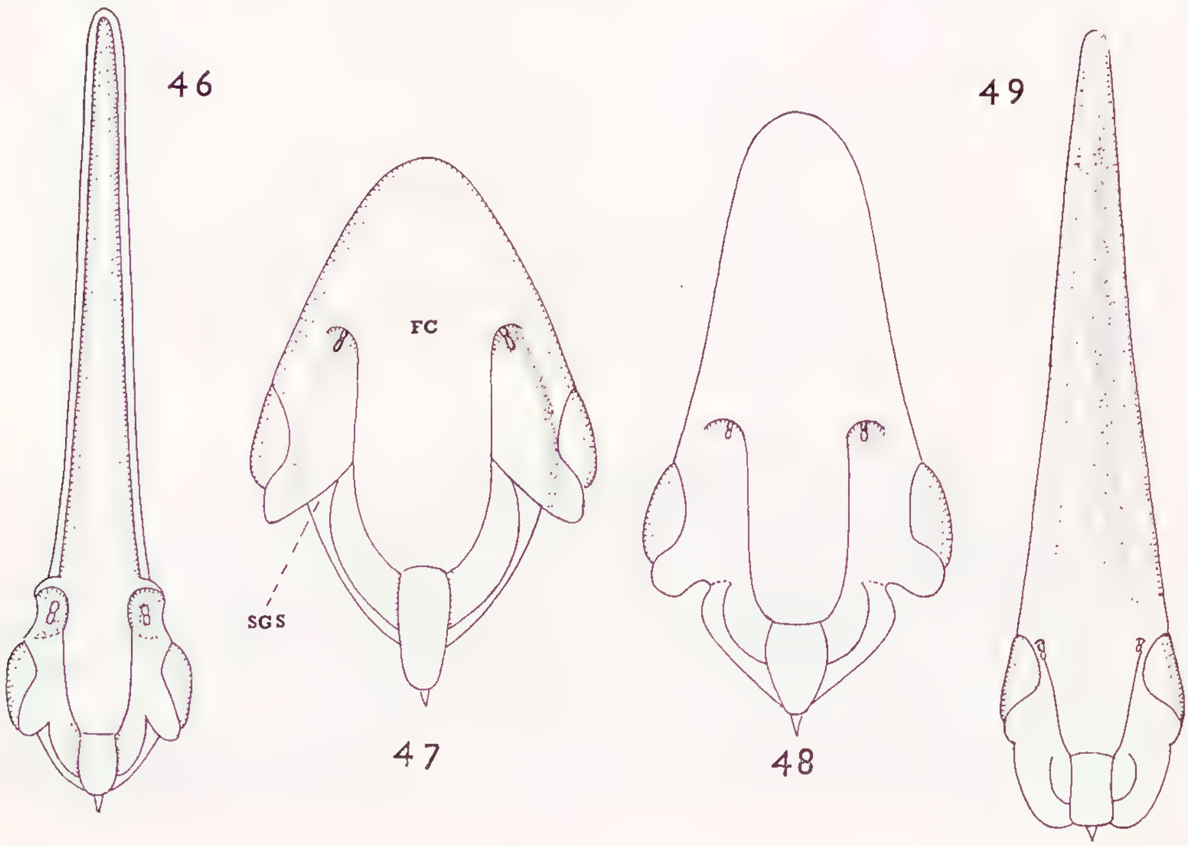


Figure 49. *Paradorydium menalaus* (Kirkaldy) (P 0: S 12)

This is a climax species of the genus *Paradorydium* Kirkaldy. While in the heads of representatives of the Cephalelini the ocelli are situated on the disc of the crown, in the Paradorydiini, they lie on its margin.

The heads illustrated in figs 50–55 all have narrowly produced heads. They belong to widely separated subfamilies and all but one have dorsal ocelli.

Figure 50. *Uloprora risdonensis* Evans (P 6: S 8)

The head of this ulopid, like that of another aberrant species in the same tribe (*M. sahlbergorum,* fig. 12) has unusually extensive genae. In consequence, the lora are widely separated from the anterior margins of the eyes.

Figure 51. *Ahenobarbus assamensis* Distant (P 0: S 12)

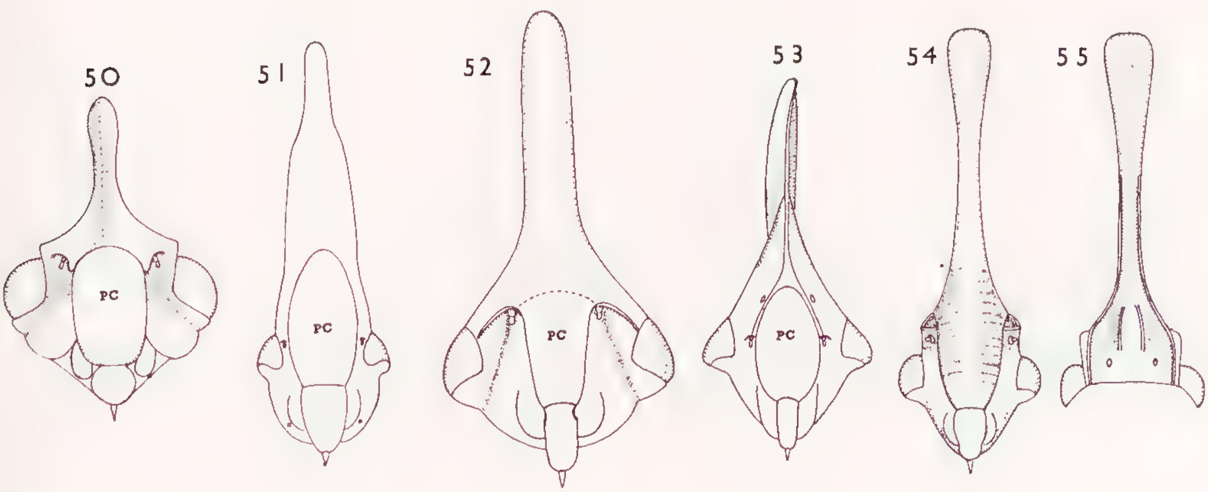
The Hylicidae, although highly specialized, are undoubtedly an ancient group of leafhoppers and most of the comprised genera are only distantly related to each other. In addition to *A. assamensis,* several species have narrowly produced heads (*see* figs 62, 63) and all have dorsal ocelli, the eyes close to the sides of the postclypeus, and weakly developed antennal ledges.

Figure 52. *Ledraprora compressa* Evans (P 3: S 10)

The Thymbrini, a tribe of the Ledrinae are confined to Australia and New Zealand. Their ocelli may be ventrally, marginally, or dorsally situated. One of their characteristics is the possession of strong transverse antennal ledges which separate the postclypeus widely from the eyes.

Figure 53. *Adelungia calligoni* Oshanin (P 2: S 8)

Like the Thymbrini, the Melicharellinae are of restricted distribution, being confined to the Eremian zone of the Palaearctic region. They, likewise, have species with ventral and dorsal ocelli. *A. calligoni* is the only cicadellid known to me which has ventral ocelli and an extensively produced head.



Figures 54, 55. *Namsangia garialis* Distant (P 1: S 12)

This is the most aberrant species of the several belonging to the Cicadellinae which have extensively produced heads.

Figures 56–60 illustrate some examples of grotesque developments in leafhopper heads.

Figure 56. *Euleimonios flavidiventris* Stål (P 2: S 12)

The extensive lora in this head, which overlap the anteclypeus laterally, are not continuous with the ventral surface of the sucking pump.

Figure 57. *Cornutipo tricornis* (Evans) (P 10: S 4)

Although, with its horn-like projections, this head appears highly specialized, it retains primitive features. Thus, the posterior apices of the lora are close to the inner margins of the antennal ledges and the maxillary sense organs are less anteriorly placed than is usual in the Eurymelidae.

Figure 58. *Listrophora evansi* Boulard (P 1: S 10)

It is seemingly impossible, in this grotesque head, to recognize the line of separation of the genae from the maxillary plates.

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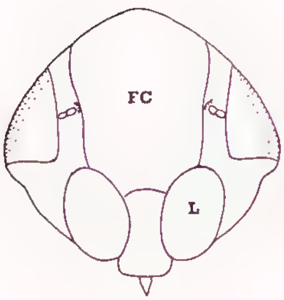

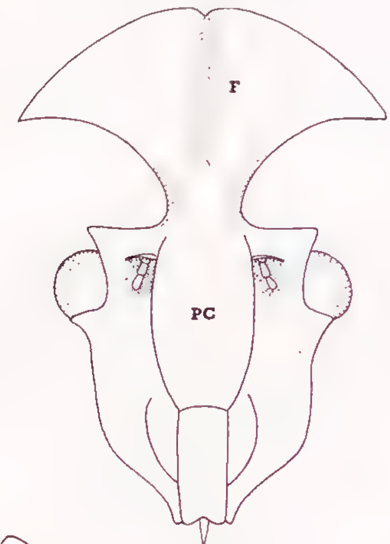

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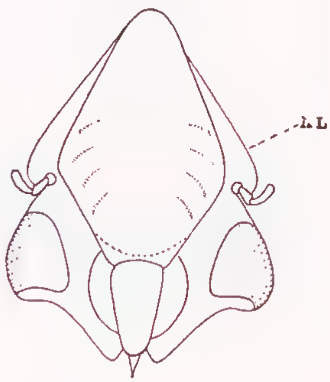

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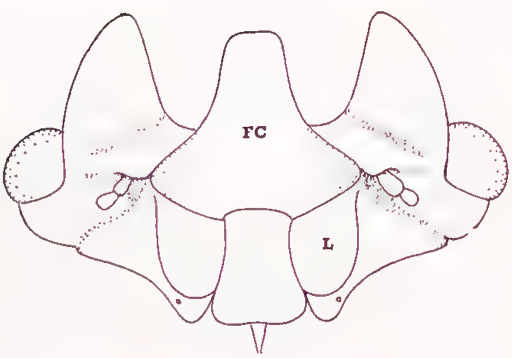

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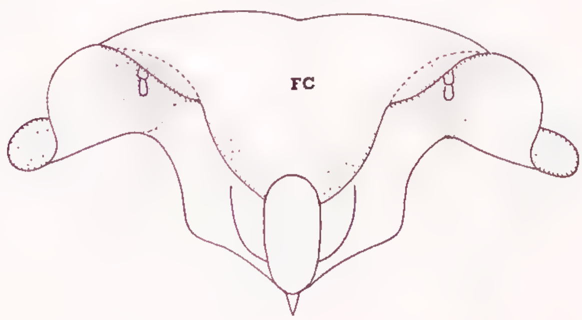


Figure 59. *Stenotortor madangensis* Evans (P 0: S 14)

This head has a higher *S* rating than any of the others illustrated. Unusual features include the extreme flattening of the face; the extension of the posterior apices of the lora to between the anterior margins of the eyes, and the bordering of the head, postero-laterally, by the antennal ledges.

Figure 60. *Evansiola kuscheli* China (P 1: S 10)

The head of *E. kuscheli* extends, laterally, well beyond the sides of the rest of the body and, like those of all the Myerslopiini, lacks ocelli. In the head of a less bizarre form belonging to the same genus, *E. selkirki* Evans, the genae are laterally emarginate anteriorly, as well as below the antennae, so that their line of junction with the maxillary plates can be recognized (Evans, 1968, fig. 3, E).

Figs 61–63 illustrate heads of insects belonging to two different families of the Cicadelloidea, which have heads with long, narrow, frontal extensions.

Figure 61. *Vangama steneosaura* Distant (P 4: S 6)

This is the sole recorded representative of the Evacanthini to have such an extensively produced crown. It is of interest to note how this highly specialized head retains traces of subgenal sutures.

Figure 62. *Wolfella krameri* Boulard (P 0: S 10)

Both this head, and the one illustrated in fig. 63, could equally well have been included in the group of bizarre heads.

Figure 63. *Wolfella caternaulti* Spinola (P 1: S 8)

The distinctiveness of the frons is more apparent in this figure than in either of the two adjacent ones.

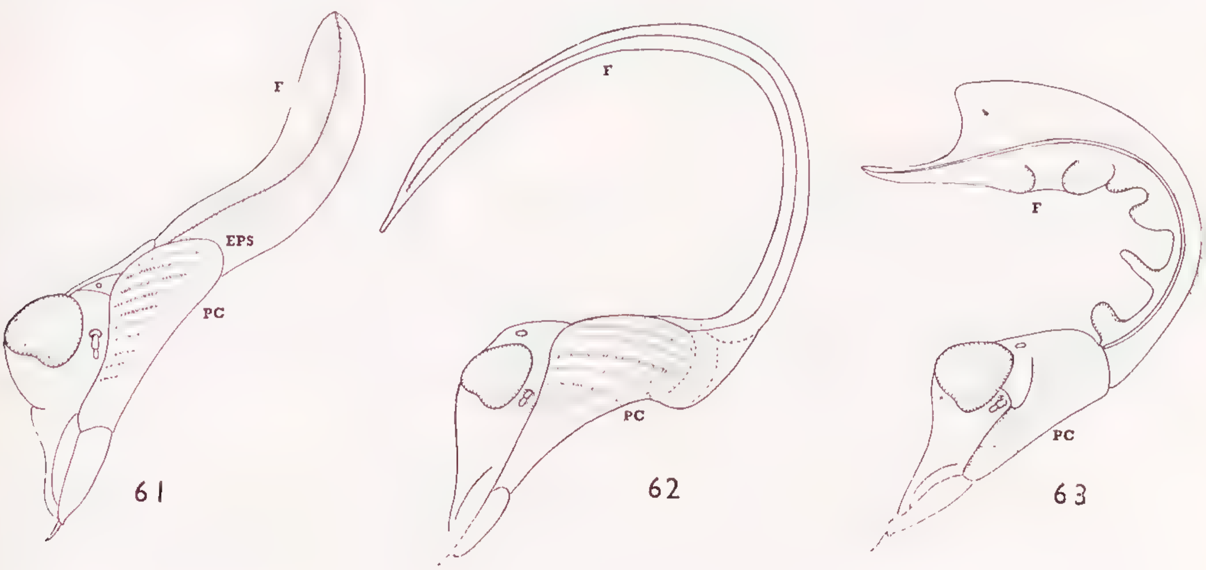
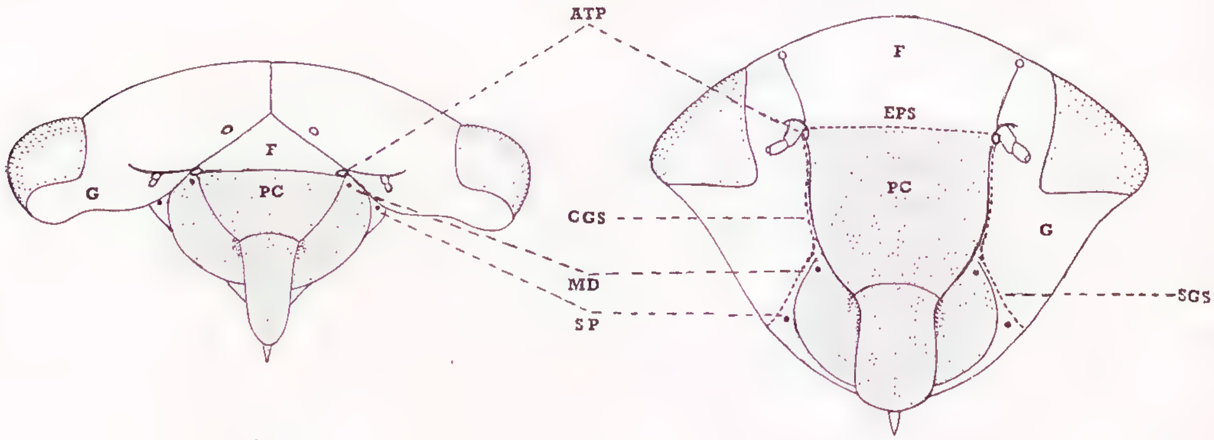


Figure 64. Reconstruction of primitive leafhopper head (based on figs 1 and 2).

Figure 65. Head based on fig. 22 with obsolete sutures added.



5. GENERAL DISCUSSION

I. *Generalized and Specialized Heads*

In the most generalized of the leafhopper heads illustrated (figs 1, 2), the maxillary plates, including the maxillary sense organs, are largely concealed by the extensive lora and they are separated from the genae by subgenal sutures. The mandibular levers are attached to the cranium close to the junctions of the subgenal and epistomal sutures, and they are also adjacent to the anterior tentorial pits and the antennal bases. The epistomal suture, which is transverse, is situated between the eyes, the transverse antennal ledges, and the anterior margins of the eyes, and it forms the anterior margin of a separately defined frons. The ocelli are on the face of the head adjacent to a three-sided, or a V-shaped, postfrontal suture.

In heads of representatives of the two dominant present-day leafhopper groups (figs 22–24), the lora may be small, or of medium size. The extensive maxillary plates, and the maxillary sense organs, are exposed and the former are continuous with the genae. Subgenal and epistomal sutures are lacking and likewise a separately defined frons. Antennal ledges may also be lacking and, if retained, form the lateral boundaries of the hind margin of the face. The ocelli may be marginally, or dorsally, situated and if a postfrontal suture is retained, then it lies close to the hind margin of the face, or on the crown of the head.

Apart from the loss of landmarks provided by the basic cephalic sutures the principal differences between the generalized cicadellid heads and those referred to in the last paragraph, is the wide separation, in the latter, of the lora, posteriorly, and hence of the points of attachment of the mandibular levers from the antennal bases and the anterior tentorial pits.

II. *Evolutionary Trends*

The principal trends evident in the heads of leafhoppers are a tendency for the progressive extension of the postclypeus posteriorly accompanied by the backward movement of the antennae and the anterior tentorial pits. Independently of this trend, since it is not related to the pull of the cibarial muscles, is a tendency for the ocelli to migrate posteriorly and to become dorsally, instead of ventrally, situated.

In respect to shape the principal trends are for heads to become progressively, either narrowly, or broadly, produced and when broadly, then subsequently flattened.

III. *Head Stability*

While the Cicadelloidea differ from other superfamilies comprised in the Auchenorrhyncha in their variable head developments, insects comprised in several of its subdivisions nevertheless have completely stable heads. It is possible also, that some groups with variable heads may be artificial rather than natural, ones.

Examples of groups with stable heads are the Membracidae, Eurymelidae, Macropsinae, Idiocerinae and Cicadellinae. Groups with variable heads include the Ulopini, Ledrini, Stenocotini, Jassinae and Penthimiinae.

IV. *Some Factors possibly associated with Head Shape*

Many of the unusual shapes of leafhopper heads are clearly of an adaptive nature. Thus, flattened heads enable an insect to press closely against, and to blend with, a leaf or branch (figs 36–45, 59), and long, narrow, heads may also aid concealment (figs 46, 49).

There are, however, many leafhoppers which have unusual heads seemingly lacking adaptive features.

Some of these occur on islands and their peculiarities may be associated with population isolation and a consequent period of genetic instability (figs 36, 60). Others, however, live in continental areas (figs 56, 58, 61, 63).

V. *Head shape and Structure as a guide to Classification*

Several years ago I suggested the Cicadellidae could be separated into two series, the Ulopides and the Macropsides, the genera comprised in the former having, supposedly, been derived from a ulopine, and in the latter, from a macropsine stem (Evans, 1947).

No useful purpose would be served by repeating arguments used to support this suggestion, but a comparison of fig. 6 with fig. 8 will demonstrate the nature of the differences which separate the heads of insects comprised in these two primitive groups.

Since the Membracidae, Aetalionidae, Biturritidae and Nicomiidae comprise genera more closely related to each other than they are to genera of any of the other cicadelloid families, much is to be said in favour of Strümpel's segregation of these families into a single unit of classification (Strümpel, 1972). It

is, nevertheless, unfortunate that category limitations have made necessary the assignment of these groups to a superfamily, since this, misleadingly, suggests the Membracoidea have a degree of distinctiveness corresponding with those of the other superfamilies of the Auchenorrhyncha.

While the Membracoidea can be regarded as a sister group of possibly all the other cicadelloid families collectively, it is the common ancestor of the Membracoidea and the Cicadelloidea which corresponds in distinctiveness with the Cercopoidea and the Cicadoidea.

VI. *A Comparison of the Evolutionary Levels of the Heads of the Cicadelloidea, Cercopoidea and Cicadoidea*

The heads of cicadas and cercopoids are always primitive anteriorly and specialized posteriorly. Thus, insects in both groups have heads in which the anterior tentorial pits, the position of the attachment of the mandibular levers, and the antennal bases, are all adjacent to each other, while the frons and ocelli have lost their original ventral situation and are on the crown. It is of interest to note, accordingly, that among the Cicadelloidea there are not only species with primitive anterior head features and specialized posterior ones (figs 8, 38), but also others in which this situation is reversed (fig. 14).

Previously I have suggested the heads of cicadelloids might owe their potential for variability to their lack of a complete tentorium (Evans, 1938). Nevertheless, in spite of their many and varied heads developments, which may, or may not, be associated with tentorial reduction, among them are still to be found insects whose heads retain, collectively, a greater assemblage of primitive head features than are to be found in the heads of any cicadas or cercopoids. Thus, apart from lacking a median ocellus, such as is present in cicada heads, and in having a reduced tentorium, the heads illustrated in figs 1 and 2, as well as retaining all the primitive features of cicada and cercopoid heads, have the following additional ones: anteriorly situated antennae; a transverse epistomal suture, in front of, or between, the eyes; subgenal sutures; a ventral frons, and ventral ocelli.

6. THE EXTERNAL FEATURES OF THE HEADS OF THE CICADELLOIDEA

I. *Sutures and clefts*

Epistomal suture. In leafhoppers with primitive heads this suture is transverse and lies entirely in front of the eyes and the lora, posteriorly, terminate close to its lateral apices (figs 1, 2).

From such heads have developed ones in which, while the suture remains transverse, and in front of the eyes, the lora no longer terminate close to its apices, but are more anteriorly situated (figs 5, 18).

In further developments the distance separating the lora from the apices of the epistomal suture increases although the suture itself remains between the eyes (figs 8, 11, 17, 52). This suture may also become posteriorly arched (figs 14, 16), or obliterated, and in such instances the postclypeus becomes continuous with the frons (figs 6, 7, 19).

Subgenal suture. The position and extent of this suture is often difficult to determine. Thus, while it can be readily recognized in the heads of many ulopines (figs 8–13), it is absent or obscure in the heads of most leafhoppers. In the head illustrated in fig. 41 there are a pair of lateral channels on each side of the postclypeus which terminate at the tentorial pits. These have been labelled "subgenal sutures", but this possibly is an error.

Clypeogenal suture. The clypeogenal suture is the cleft which extends from near the posterior apices of the lora to the tentorial pits and the antennal bases and it separates the postclypeus laterally from the genae. It varies in length and may be short (figs 15, 18), or long (figs 12, 16), and it is lacking in primitive heads (figs 1, 2). Its homologies are uncertain but as it extends from the genal margin to the lateral apices of the epistomal suture, it may be derived, in part, from the subgenal suture (*see* figs 8, 11, 12, 13 ,15).

In order to explain this suggestion further a hypothetical primitive head, based on figs 1 and 2, is illustrated in fig. 64 and beside it (fig. 65), one derived from the head shown in fig. 22. These figures are self explanatory.

A clypeogenal suture is indicated in the head of a Thysanopteran illustrated in Matsuda, 1965 (fig. 17,B). As this terminates posteriorly at the point where the subgenal sutures meet the epistomal suture, it cannot be homologous with the clypeogenal suture of leafhopper heads since the areas bordering it laterally are of pre-, and not postgenal, origin. Nor can the clypeogenal sutures of the heads of Psocoptera be homologous with those of cicadelloids, since in the former the anterior tentorial pits lie at its anterior apices. Consequently the whole of the suture surrounding the postclypeus in psocid heads must represent the epistomal suture.

II. *Clypeus and lora*

The clypeus is "the area of the cranium upon which arise the dilator muscles of the cibarium and the dorsal muscles of the buccal cavity, or the part of the stomadeum just within the mouth" (Snodgrass, 1935).

In Homoptera it is bounded laterally by the "lora", or "mandibular plates", and the identity of these presents the most intriguing problem associated with the Homopteran head.

In a recent paper Parsons has discussed three separate theories of the origin of the loral lobes (Parsons, 1974). These, respectively, are the hypopharyngeal, genal-sub-genal and the clypeal theories.

Two other hypotheses have been advanced. According to one the lora may have developed from paraclypeal lobes identical with those that occur in the heads of larval Megaloptera (Ferris, 1943). The other, which may be called the "stipal hypothesis", is based on the assumption that the lora and maxillary plates are homologous structures and that their respective stylets are likewise homologous. Accordingly, as the maxillary stylet is presumed to have been derived from the lacinia of a biramous appendage, so must the mandibular stylet have a similar origin. This leads on to the assumption that the earliest insects had three pairs of biramous mouthparts and that in the Mandibulata the first pair have become reduced and modified (Heslop-Harrison, 1956).

In her *Conclusions* Parsons selected the hypopharyngeal theory as furnishing the most generally acceptable explanation of the origin of the lora, and she suggested that the clypeal theory was the most improbable one.

The generalized mandibulate head figured in her paper, for purposes of comparison with the heads of Hemiptera, is that of an Orthopteran and in her two diagrams illustrating Orthopteran heads, the clypeus, posteriorly, is shown as laterally continuous with a narrow subgenal area. In the heads of the supposedly primitive cicadelloids illustrated in figs 1 and 2, not only is there no evident association between the clypeus and the genae, but subgenae are lacking. They are also lacking in the heads of larval Mecoptera, which, surely, retain more primitive features than the heads of any Orthoptera? (*See* Matsuda, 1965, fig. 21B.)

Apart from the lack of genae, the heads of larval Mecoptera resemble those of the primitive leafhoppers referred to above in having the clypeus situated entirely in front of the eyes, and the antennae in alignment, or approximately so, with the transverse epistomal suture, which meets the subgenal sutures laterally, adjacent to the position of the anterior tentorial pits.

For the above reasons, and also because in cicadelloids the lora lie entirely in front of the genae, it seems improbable that they could be either of genal, or subgenal, origin.

One of Parsons' major criticisms of the clypeal theory of loral origin is concerned with innervation and another with the fact that this theory not only is the most complex of the three hypotheses, but that it requires two separate independent processes.

Her third major criticism is that it makes necessary the assumption that the originally united clypeus and lora became increasingly separated during the evolutionary development of the heads of Homoptera, while exactly the opposite phylogenetic trend is evident in the heads of Heteroptera. Moreover, this trend in the Heteroptera is consistent with both the genal-subgenal and with the hypopharyngeal theories of loral development.

The genal-subgenal theory has already been referred to. In respect to the hypopharyngeal hypothesis, surely, since the lora, as stated by Parsons, seemingly lack close association with the greater part of the postclypeus in the heads of the more specialized Cicadelloidea (*see* figs 12, 41, 65), although they embrace it laterally for the whole of its length in generalized ones (figs 1, 2), this fact, contrary to Parsons' interpretation, would seem to support the clypeal, rather than hypopharyngeal interpretation of loral development. For, otherwise, the reverse situation would presumably obtain, that is to say in primitive forms the lora would lack close association with the greater part of the postclypeus even although they might acquire it in subsequently evolved ones.

III. *Maxillary plates and genae*

In a recent paper in which the possible morphological significance of the maxillary plates of the Auchenorrhyncha was discussed, the claim of Parsons (1964) that this plate is not part of the maxilla, but rather a non-appendicular parietal lobe, was rejected, and it was suggested that a sense organ present on the maxillary plates might have been derived from the maxillary palp (Evans, 1973).[1]

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[1] Since this paper was written I have become aware that the same suggestion had previously been made by Heslop-Harrison (1956).

If the structure referred to is of palpal origin, then its reduction may have been associated with the growth of the lora, which in the heads of the more primitive leafhoppers overlap the greater part of the maxillary plates.

In some such heads the sense organ is situated at the base plates, close to where they meet the genae (figs 9, 15). Accordingly, in heads in which the genae and maxillary plates are continuous, the position of the organ might make possible the determination of the extent of the two components of the maxillary plates. Such a possibility, however, is not supported by an examination of a series of heads, for, while an increased genal and a reduced maxillary component might be an expected development (figs 16, 29–31) the extreme anterior position of the sense organ in the heads of most eurymelids (figs 19, 31) seemingly disproves the suggestion.

IV. *Frons*

Ferris has stated that the frons is nothing more than the facial portion of the antennal segment and not a separate morphological element (Ferris, 1943); also, that the postfrontal suture, because of its origin, must, at its greatest extent, pass between the compound eyes and the antennal foramina.

If Ferris is correct in his definition of the frons and in his description of the postfrontal suture, and there is no reason to suppose otherwise, then the frons and the postfrontal suture in their most primitive known condition in cicadelloid heads must be as illustrated in figs 2 and 8, and doubtless the supra-antennal ledges must be derived from the apical parts of the suture. It must, accordingly, be assumed that the condition in which the frons occurs as a separate and distinct sclerite is a secondary, even although an ancient, development, both in the Cicadelloidea (figs 10, 14, 17, 61, 63) and in the Fulgoroidea.

V. *Ocelli*

In leafhoppers with primitive heads there is little, or no, development of a crown, hence the ocelli are necessarily ventral, or situated on a vertical plane, and they are widely separated from the hind margin of the face (figs 1–6, 17–19). In some species with more specialized heads, although ocelli remain ventral in position they may be close to the hind margin of the face (figs 14, 16, 22, 32, 33); in marginal depressions (certain Megophthalmini and Stenocotini), or lie on a marginal rim separating the face from the crown (figs 29–31).

The transfer of the ocelli from the face to the crown of the head has been achieved in several ways. In the Penthimiinae, for example, a series can be traced from insects with convex heads and ventral ocelli to others wih flattened spatulate head and dorsal ocelli (Evans, 1937, Text—fig. 1). However, in the heads of the Ledrini, which superficially resemble some penthimiids, no corresponding series can be followed, nor can it either in the Ulopini, from which it is supposed the Ledrinae were derived.

Bearing in mind the presumed selective advantage of dorsal ocelli it is surprising to find that, while ocellar rudiments in the nymphs of certain Thymbrini (*Rhotidoides* spp.) are on the crown, in adult insects of the same species the ocelli are ventrally situated (Evans, 1969). In a few cicadellids, particularly in the Ulopinae and Typhlocybinae, ocelli are lacking.

VI. *Antennae and anterior tentorial pits*

While the antennae of most cicadellids have short flagellae, in a few groups, such as in the Coelidiinae and Platymetopiini, they are very long.

Their position on the head is variable. Thus, while on the heads of the more primitive forms they may be approximately in alignment with the anterior margins of the eyes (figs 1–7), they may also lie between their hind margins (figs 8–10), or even be more posteriorly situated (fig. 12). In highly specialized species the antennae are usually situated posterior to the eyes (figs 36, 38, 41, 45, 46) but they may also be placed near their centres (figs 53, 61–63).

The antennal muscles are attached to the dorsal arms of the tentorium (Matsuda, 1965, p. 22). This suggests the possibility, in cicadelloids that they have either migrated from the dorsal to the anterior arms, or else, in instances where the tentorium is unbranched, that true anterior arms are lacking.

7. SOURCE OF MATERIAL

All the insects illustrated in this paper are contained in the author's leaf-hopper collection. This has been assembled, with the co-operation of entomological colleagues, over a long period of years and, apart from the one in the British Museum may contain more species of a particularly interesting nature than are to be found in any other collection. When no longer needed for purposes of personal research it will be transferred to the Australian Museum.

It is regrettable, with the growth of nationalism in many parts of the world, that regional collections of insects are tending to be strengthened at the expense of those concerned with the fauna of the world as a whole, since, for studies of a varied nature, of which the present one is an example, collections representative of the world fauna are an absolute necessity.

8. ACKNOWLEDGMENTS

My interest in the structure of the heads of Homoptera is of long standing and my first paper on this subject was published nearly 40 years ago. Interests can grow stale, and the research incorporated in the present paper would never have been undertaken had it not been for the stimulus derived from long continued correspondence with Dr Margaret Parsons, to whom appreciative thanks are expressed. I am grateful also to my wife for help in the preparation of the illustrations.

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APPENDIX

The Systematic Position; Distribution; Primitive and Specialized Ratings and Periods of Possible Origin of Species Illustrated in Figures 1–63

Although remains, consisting principally of wings, of many Permian and Triassic cicadelloids have been described, few have been recorded from Jurassic and Cretaceous strata (Evans, 1964). For this reason the possible periods of geological origin, listed in the right-hand column, are not based on fossil evidence but on a balance of structural and distributional factors.

Fig.	Name	Systematic position	Distribution	Rating P	Rating S	Periods of possible origin
1	*Coloborrhis reticulata* Evans	Cicadellidae Ulopinae Ulopinae	Madagascar	13	2	(*See p. 080*).
2	*Darthula hardwickii* Gray	Aetalionidae Darthulinae	S.E. Himalayas	14	0	Jurassic.
3	*Melizoderes darwini* Funkhouser.	Biturritidae	Neotropical region.	9	4	Cretaceous.
4	*Holdgatiella chepuensis* Evans.	Membracidae	Chile	9	4	Cretaceous.
5	*Tropidaspis carinata* Fabricius.	Biturritidae	Neotropical region.	3	9	Cretaceous.
6	*Stenopsoides turneri* Evans.	Cicadellidae Macropsinae	S.W. Australia	10	2	Cretaceous.
7	*Jassulus brunneus* Evans.	Cicadellidae Jassinae Jassini	Tropical Africa	9	4	Cretaceous.
8	*Woodella wanungarae* Evans.	Cicadellidae Ulopinae Ulopini	E. Australia (montane fauna).	7	8	Jurassic.
9	*Austrolopa brunensis* Evans.	Cicadellidae Ulopinae Ulopini	S.E. Australia (montane fauna).	7	8	Jurassic.
10	*Moonia variabilis* Distant.	Cicadellidae Ulopinae Ulopini	India	8	5	Jurassic.
11	*Taslopa montana* Evans.	Cicadellidae Ulopinae	S.E. Australia (montane fauna).	6	6	Jurassic.
12	*Megulopa sahlbergorum* Lindberg.	Cicadellidae Ulopinae Ulopini	Israel	6	6	Cretaceous.
13	*Novolopa townsendi* Evans.	Cicadellidae Ulopinae	New Zealand	6	6	Jurassic.

APPENDIX—*continued*

Fig.	Name	Systematic position	Distribution	Rating P	Rating S	Periods of possible origin
14	*Caelidoides tristis* Signoret.	Cicadellidae Coelidiinae (?)	Madagascar	4	6	Cretaceous.
15	*Khyphocotis tessellata* Kirkaldy.	Cicadellidae Ledrinae Stenocotini	Australia	8	2	Cretaceous.
16	*Tartessus* sp. (nymph)	Cicadellidae Tartessinae	Australia	4	7	Cretaceous.
17	*Koebelia californica* Baker.	Cicadellidae Ledrinae Koebeliini	California	8	6	Jurassic.
18	*Agalliana pauliana* Evans.	Cicadellidae Agalliinae	Madagascar	5	8	Cretaceous.
19	*Opio multistrigia* (Walker).	Eurymelidae Ipoini	Australia	5	5	Cretaceous.
20	*Eryapus gibbus* Evans	Cicadellidae Acostemminae (?)	Madagascar	3	10	Tertiary.
21	*Tiaja* sp.	Cicadellidae Ulopinae (?) Megophthalmini	W.N. America	4	8	Jurassic.
22	*Idiodonus cockerelli* Ball.	Cicadellidae Deltocephalinae	N. America	2	12	Tertiary.
23 24	*Cicadella spectra* (Distant).	Cicadellidae Cicadellinae	Tropics and sub-tropics generally.	1	12	Tertiary.
25 26	*Chiasmus varicolor* (Kirkaldy).	Cicadellidae Deltocephalinae	Widely distributed in warmer parts of world.	1	10	Tertiary.
27	*Glossocratus afzelii* (Stål).	Cicadellidae Hecalinae Hecalini	South Africa	3	10	Tertiary.
28	*Eupelix cuspidata* (Fabricius).	Cicadellidae Hecalinae Eupelicini	Warmer regions of Palaearctic.	0	12	Tertiary.
29	*Selenomorphus nigrovenatus* Evans.	Cicadellidae Jassinae Selenomorphini	New Caledonia	4	10	Tertiary.
30	*Drabescus heroni* Evans.	Cicadellidae Drabesciane	N.E. Australia and New Guinea.	3	8	Tertiary.

APPENDIX—*continued*

Fig.	Name	Systematic position	Distribution	Rating P	Rating S	Periods of possible origin
31	*Selenocephalus* sp.	Cicadellidae	Central Africa	3	8	Tertiary.
32	*Tartessoides griseus* Evans. (♂)	Cicadellidae Tartessinae	Australia (semi arid regions).	3	8	Tertiary.
33	(♀)	....	....	..	..	....
34	*Stenotartessus mullensis* (Evans). (♀)	Cicadellidae Tartessinae	Australia	3	8	Tertiary.
35	(♂)	....	....	..	..	....
36 37	*Coloborrhis ledroides* Evans.	Cicadellidae Ulopinae Ulopini	Madagascar	4	6	Tertiary.
38	*Platyscopus badius* Evans.	Cicadellidae Penthimiinae	S.W. Australia	3	10	Tertiary.
39	*Mapochia collaris* Distant.	Cicadellidae Hecalinae Paradorydiini	South Africa	0	12	Tertiary.
40 41	*Occinirvana eborea* Evans.	Cicadellidae Nirvaninae Occinirvanini	W. Australia	0	8	Jurassic.
42	*Dorycephalus hunnorum* Emeljanov.	Cicadellidae Hecalinae Dorycephalini	U.S.S.R.	2	10	Cretaceous.
43	(See 38).					
44 45	*Ledropsis crocina* Distant.	Cicadellidae Ledrinae Ledrini	Australia	3	8	Jurassic.
46	*Cephalelus bulbosa* Evans.	Cicadellidae Ulopinae Cephalelini	W. Australia	3	8	Jurassic.
47	*Cephalelus minutus* Evans.	Cicadellidae Ulopinae Cephalelini	Southern Australia.	3	9	Jurassic.
48	*Cephalelus ianthe* (Kirkaldy).	Cicadellidae Ulopinae Cephalelini	S.E. Australia	3	8	Jurassic.
49	*Paradorydium menalaus* Kirkaldy.	Cicadellidae Hecalinae Paradorydiini	S.E. Australia	0	12	?

APPENDIX—*continued*

Fig.	Name	Systematic position	Distribution	Rating		Periods of possible origin
				P	S	
50	*Uloprora risdonensis* Evans.	Cicadellidae Ulopinae Ulopini	E. Australia	6	8	Jurassic.
51	*Ahenobarbus assamensis* Distant.	Hylicidae	Assam	0	12	Cretaceous.
52	*Ledraprora compressa* Evans.	Cicadellidae Ledrinae Thymbrini	W. Australia	3	10	Cretaceous.
53	*Adelungia calligoni* Oshanin.	Cicadellidae Melicharellinae Adelungiini	Turkey (Eremian sub-region).	2	8	Cretaceous.
54 55	*Namsangia garialis* Distant.	Cicadellidae Cicadellinae	S.E. Asia	1	12	Tertiary.
56	*Euleimonios flavidiventris* Stål.	Cicadellidae Deltocephalinae	S.E. Australia	2	12	Tertiary.
57	*Cornutipo tricornis* (Evans).	Eurymelidae Ipoini	Tropical Australia.	10	4	Cretaceous.
58	*Listrophora evansi* Boulard.	Cicadellidae Hecalinae Listrophorini	Central Africa	1	10	Tertiary.
59	*Stenotortor madangensis* Evans.	Cicadellidae Nirvaninae Nirvanini	New Guinea	0	14	Tertiary.
60	*Evansiola kuscheli* China.	Cicadellidae Ulopinae	Juan Fernandez Island.	0	12	Tertiary.
61	*Vangama steneosaura* Distant.	Cicadellidae Aphrodinae Evacanthini	N.W. India	4	6	Tertiary.
62	*Wolfella krameri* Boulard.	Hylicidae	Central Africa	0	10	Tertiary.
63	*Wolfella caternaulti* Spinola.	Hylicidae	Central Africa	1	8	Tertiary.

Abbreviations used in Figures

AC, anteclypeus; AL, supraantennal ledge; AT, anterior arm of tentorium; ATP, anterior tentorial pit; CGS, clypeogenal cleft; CS, coronal suture; EPS, epistomal suture; F, frons; FC, frontoclypeus; G, gena; L, lorum; M, maxilliary stylet; MD, attachment of mandibular lever; MXP, maxillary plate; PC, postclypeus; PFS, postfrontal suture; PT, posterior tentorial bar; SGS, subgenal suture; SP, sensory process.

NEW POGONOPHORA FROM INDONESIA

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Figures 1–4 Manuscript received 3rd April, 1974

SUMMARY

Seven species of Pogonophora were obtained from a depth of 525–570 m, at a station near Halmahera Island in the Molucca Group, by the *Te Vega* Expedition. New species of *Unibrachium, Siboglinum and Lamellisabella* are described.

INTRODUCTION

A small collection of Pogonophora made by the research vessel *Te Vega* in 1963 was deposited in the Australian Museum (AM) by Dr A. A. Racek of Sydney University, and has been sent to me for identification. It includes seven species, all from one locality in the outer part of Teluk Kau, a large bay on the oceanic side of Halmahera Island in the Molucca Group.

Nineteen species of Pogonophora are already known from the Indonesian region in general, collected by the *Siboga, Galathea* and *Vitiaz* (Kirkegaard, 1956; Ivanov, 1960, 1963; Southward, 1961). The nearest locality to the *Te Vega* station is a *Vitiaz* station off the north coast of Morotai, from which two species of *Siboglinum* were recorded (Ivanov, 1960, 1963).

Three of the *Te Vega* species can confidently be described as new, while a fourth may possibly belong to one of the species found by Ivanov off Morotai. The other three species are represented by empty tubes. The terminology used in the descriptions follows that of earlier papers as far as possible (particularly Ivanov, 1963), but because of the renewed argument that pogonophores are not deuterostomes but protostomes (*see for example* Southward, 1971), Ivanov's terms *dorsal* and *ventral* have been replaced by the neutral *adneural* and *antineural* respectively. All material described in this paper is in the Australian Museum.

SYSTEMATIC ACCOUNT

Family **OLIGOBRACHIIDAE** Ivanov

Genus **UNIBRACHIUM** Southward

Unibrachium tenuifrenum sp. nov.

Holotype

Male from *Te Vega* station 58: 01° 31′ N, 128° 13′ E, depth 525–570 m, 27 Sept. 1963 (AM W. 6107).

Paratypes

Two immature specimens from the same station (AM W. 6108, 6114).

Description

The largest specimen is a male which is not fully mature and does not contain spermatophores; the other two are smaller and their sex cannot be determined. In each specimen the single tentacle is in rather poor condition; many long thin pinnules (about 170 x 7 μm) can be seen but their arrangement is not clear. The forepart of the body is cylindrical, about ten times as long as wide, and it has a small, rather rounded, cephalic lobe which is concave in front of the tentacle base (fig. 1, a, b). The sides of the cephalic lobe bulge a little, flanking the tentacle base. A complete groove separates the cephalic lobe from the rest of the forepart. Behind this there is a bulge on the antineural side (= ventral, Ivanov, 1963), crossed by several grooves (fig. 1, b). The smoother region that follows the bulge bears a very slight, colorless ridge of cuticle which is not at all easy to see (fig. 1, b, br,). The ridge must represent the bridle keels which are so obvious in most pogonophores. In this case the keels appear to be fused on the antineural side but separated by a wide gap on the adneural side. The remainder of the forepart is smoothly cylindrical and lacks white patches or other obvious granule-containing epidermal cells. A strong constriction separates the forepart and trunk (fig. 1, c). The anterior part of the trunk has a pair of fairly short lateral ridges containing pyriform glands in two to four irregular rows. There is a deep median groove between the ridges, on the antineural side, and a wide ciliated band on the adneural side, the same length as the ridges. This region of the trunk is equivalent to the metameric region of other pogonophores. Behind it the trunk becomes cylindrical and fairly smooth, with a few scattered papillae. The girdle region (fig. 1, d, e) is complete only in the two smaller specimens,

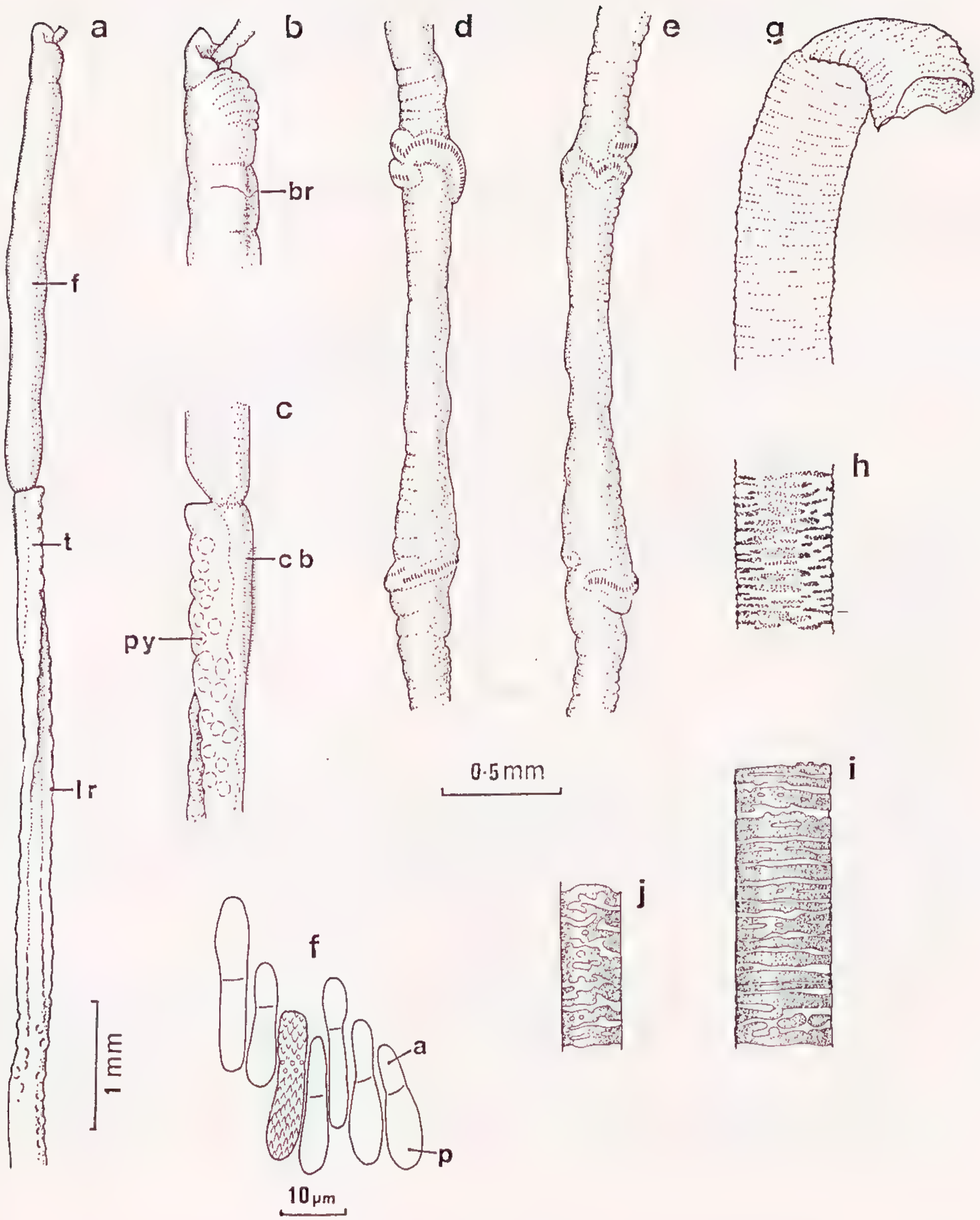

Figure 1.—*Unibrachium tenuifrenum* sp. nov. a, forepart and metameric region of trunk; b, anterior end, antineural side; c, junction between forepart and trunk, side view; d, e, two views of girdle region; f, toothed platelets, face view showing shape of head and arrangement of teeth; g, anterior tip of tube; h, brown streaks near anterior end of tube; i, middle of tube; j, tube near posterior end.

a, anterior teeth; br, bridle; cb, ciliated band; f, forepart; lr, lateral ridge; p, posterior teeth; py, pyriform gland; t, trunk.

where it consists of two girdles 1.6 to 1.9 mm apart. A larger specimen would probably have the girdles farther apart. The platelets (or toothed setae) are arranged in single rows, and their narrow heads range in length from 17 to 30 μm. There are two groups of teeth, the anterior group being slightly smaller than the posterior (fig. 1, f). There is a large papilla behind the second girdle (fig. 1, e) but the rest of the postannular region is in poor condition and the distribution of postannular papillae cannot be made out. The hind end, or opisthosoma, is missing.

The measurements of the animals are: forepart length 2.2 to 3.7 mm; forepart diameter 0.29 to 0.36 mm; length of metameric region 1.4 to 4.7 mm; length of preannular region 5.3 to 14 mm.

The tube is flexible and rather soft, brown in the middle but paling, through yellow, to colourless at either end. The thin-walled anterior tip is either collapsed or folded over (fig. 1, g). The wall is wrinkled in the anterior part of the tube and the brown colour starts as small dark flecks or streaks among the wrinkles (fig. 1, h). In the middle part there is a change to close-packed narrow brown rings (fig. 1, i) and towards the posterior end the rings become paler, less regular and more widely spaced (fig. 1, j). Finally there is a short colourless section. The largest tube (holotype) is 0.47 mm in diameter at the anterior end, 0.37 mm in the middle and 0.20 mm posteriorly, while the same measurements for the smallest tube are 0.33 mm, 0.29 mm and 0.23 mm.

Discussion

The only other species of *Unibrachium* is *U. colombianum* Southward 1972, from the Caribbean. The genus was established because this unitentaculate species had several distinctive characters separating it from *Siboglinum,* notably the lateral ridges containing many pyriform glands instead of rows of separate papillae. This feature is shared by the genera *Nereilinum* and *Oligobrachia,* and so *Unibrachium* has been placed in the family Oligobrachiidae.

The new species is remarkably similar to *U. colombianum* in all the features thought to be of generic importance, and even the ornamentation of the tube is almost exactly the same. However, *U. tenuifrenum* can be distinguished by the almost invisible bridle, because in *U. colombianum* the bridle is clearly visible, though thin and rather wavy in form. The proportions of the forepart are also different: in *U. tenuifrenum* the ratio of length to breadth is 10:1 whereas in *U. colombianum* the ratio is 20:1.

The arrangement of the girdles may be important, because in *U. colombianum* the two girdles are close together, while in *U. tenuifrenum* they are some distance apart. In addition, *U. tenuifrenum* is smaller than *U. colombianum,* their maximum tube diameters being, respectively, 0.47 and 0.8 mm, but full grown examples of *S. tenuifrenum* may be somewhat larger than those described here.

The name *tenuifrenum* describes the weak bridle of the new species, and is derived from the Latin *tenuis,* weak, and *frenum,* bridle.

Family **SIBOGLINIDAE** Caullery

Genus **SIBOGLINUM** Caullery

Siboglinum polystichum sp. nov.

Holotype

Male from *Te Vega* station 58 (see p. 2). (AM W. 6109).

Description

This is an extremely small species of *Siboglinum*, with a brittle tube ornamented with elaborate brown rings. It has proved impossible to extract the animal from its tube, but enough details can be seen through the tube wall to show that it belongs to a new species.

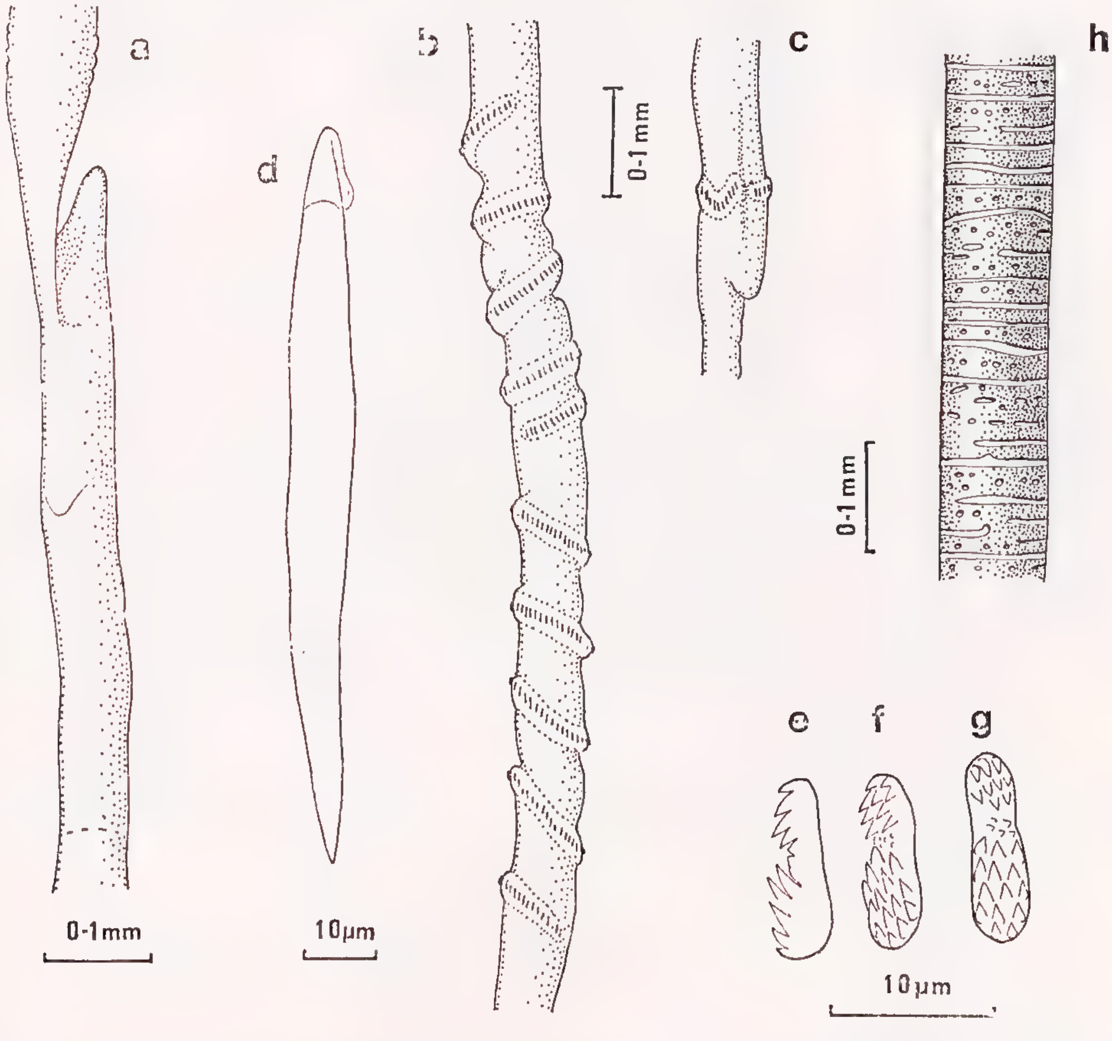

Figure 2.—*Siboglinum polystichum* sp. nov. a, forepart, antineural side, and proximal part of tentacle; b, first and second girdles; c, third girdle; d, spermatophore; e, f, g, toothed platelets, side and face views of heads; h, middle of tube.

The tentacle is very wide, nearly as wide as the body, and a few pinnules can be seen, though their arrangement cannot be made out. The moderately long cephalic lobe has lateral bulges flanking the tentacle base (fig. 2, a). The whole forepart is about 0.5 mm long and 0.06 mm in diameter, so the ratio of length to breadth is 8:1. The thin bridle can be seen very indistinctly and the keels appear to be joined on the antineural side and separate on the adneural side. The pre-annular region of the trunk is 13 mm long and contains many spermatophores, which are fusiform, about 160 μm long and 12 μm wide (fig. 1, d). The girdle region is most unusual; at first sight it seems to have eleven separate girdles (fig. 2, b, c), but close inspection shows that there are only three. The first and second girdles are very long and spiral around the body 4½ to 5 times. There is then a gap of 1.4 mm followed by the normal kind of posterior girdle composed of two half-hoops of toothed platelets (fig. 2, c). The platelets are arranged in single rows in all three girdles, and are 9–10 μm long with two groups of teeth, the anterior group being slightly smaller than the posterior. Behind the third girdle is a single papilla but the rest of the postannular region is too indistinct to show the distribution of the other papillae, and the opisthosoma is missing.

The tube is broken and the anterior end is missing. The middle part is yellow-brown and the posterior end yellow. The ornamentation consists of closely packed and anastomosing rings, which are perforated by many small clear areas, looking like rows of holes (fig. 2, h). The diameter of the middle region is 0.10 mm and the posterior region is 0.08 mm.

Discussion

In spite of a rather incomplete description it is obvious that this species is unusual in having such long girdles, and such an elaborately "perforated" tube. It shares these characters with only one known species of *Siboglinum, S. callosum* Ivanov 1971, which occurs in the Caribbean. The anterior end of the tube of *S. callosum* is segmented (Southward, 1972), but that of the new species is unknown. The middle and posterior regions of the two species' tubes are very similar and they are about the same size. The shapes of the anterior ends of the two species seem to be similar but the bridle of the new species is less strongly developed. The chief difference lies in the number of spirals the girdles make around the body, since in *S. callosum* the first and second girdles make three spirals each, giving the appearance of six girdles, which are followed by a gap and then a small and normal posterior girdle. The greater number of spirals in the new species, considered with the great geographical separation, lead me to suppose that it is distinct from *S. callosum.*

The name *polystichum* describes the multi-annulate appearance of the girdle region and is derived from the Greek *poly,* many, and *stichos,* a line of soldiers or row of rod-like objects.

Siboglinum sp.

Material examined

Two fragments of tube, one containing a mature female, from *Te Vega* station 58 (*see* p. 2). (AM W. 6110).

Description

The two fragments seem to be the anterior and posterior halves of one tube. The animal is contained in the posterior half and can be seen fairly clearly through the tube wall. It has a fairly thick tentacle bearing two rows of pinnules. The forepart is 0.9 mm long and 0.1 mm in diameter. There is a spoon-shaped cephalic lobe followed by a narrower "neck" region (fig. 3, a, b). The yellowish bridle keels fuse on both sides of the body. The metameric region of the trunk has two rows of about 40 papillae, extending over 3.5 mm and the whole preannular region is 17 mm long. There are three girdles, the first two close together and the posterior one 1.3 mm farther back. The toothed platelets are about 17 μm long

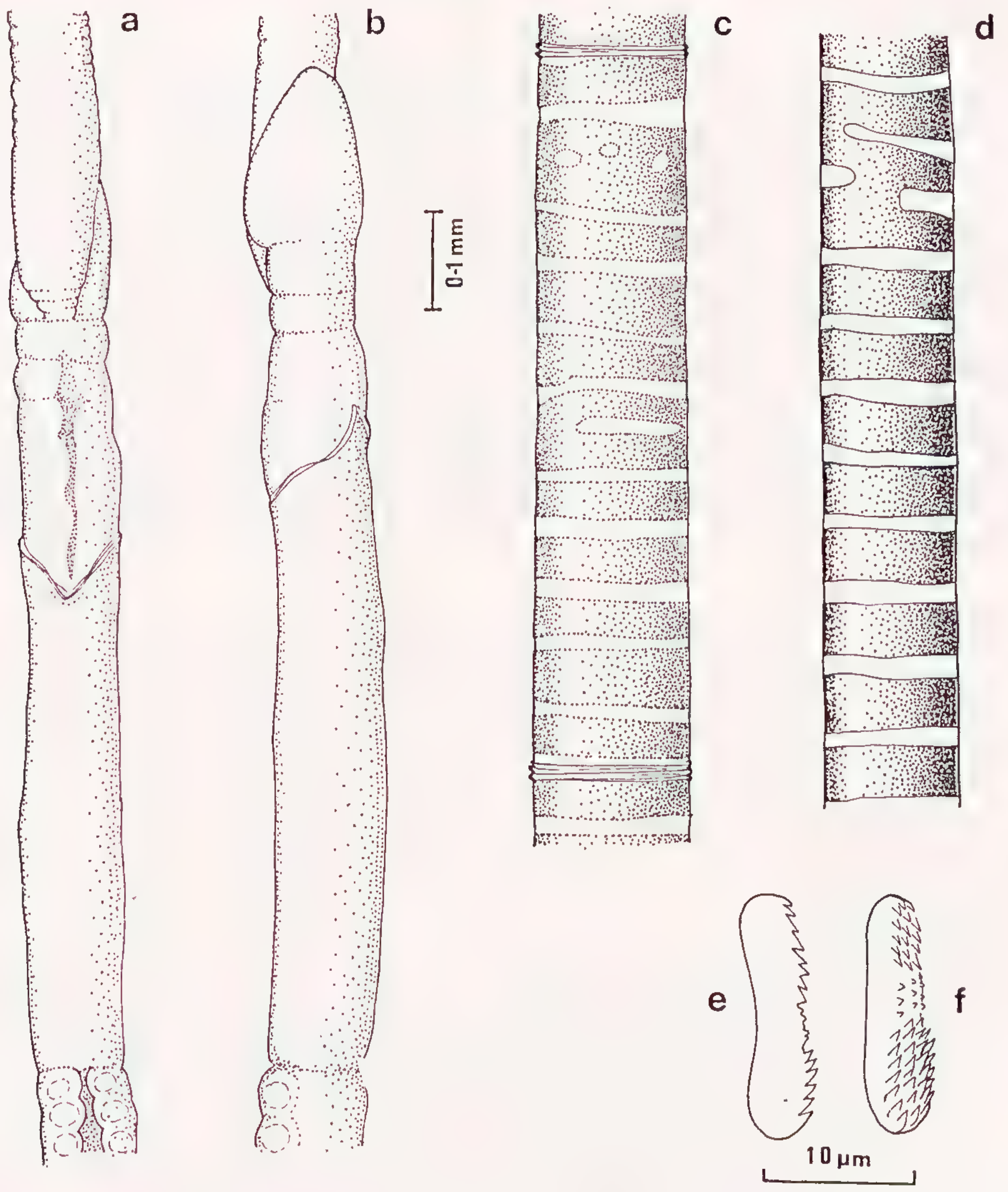

Figure 3.—*Siboglinum* sp. (*pinnulatum* ?). a, forepart, antineural side, and proximal part of tentacle; b, forepart, neural side; c, segment with rings, near anterior end of tube; d, middle of tube; e, f, toothed platelets, side and face views of head.

and are arranged in irregular single or semi-double rows. Their anterior and posterior groups of teeth are almost equal (fig. 3, e, f). The postannular region is in poor condition and the opisthosoma is missing.

The tube has a short unringed smooth-walled anterior portion, followed by red-brown rings which are regularly arranged, with straight borders, fairly close together (fig. 3, c, d). The anterior end of the tube is segmented, and where rings are present there are 10 to 13 per segment (usually 11). The segments range in length from 0.65 to 0.72 mm, while the diameter of the tube is 0.145 mm for most of its length, tapering to 0.130 mm near the posterior end.

Discussion

Segmented tubes of about this size are characteristic of several *Siboglinum* species from various parts of the world, and four are already known from the Indonesian region. Of the Indonesian species, *S. variabile* Ivanov 1960 can be excluded because it has no pinnules on the tentacle; *S. macrobrachium* Southward 1961 has the tube rings very obviously split into "doublets" and also has a smaller cephalic lobe and smaller toothed platelets; *S. sumatrense* Ivanov 1963 has the bridle keels separate on both sides of the body, and shorter tube segments. *S. pinnulatum* Ivanov 1960 seems closest to the species described above, but has the bridle keels separate on the adneural ("dorsal") side and has only eight rings per tube segment. Apart from these details the animals are very similar and, since *S. pinnulatum* was found off the north coast of Morotai in 260 m depth, not far from *Te Vega* station 58, there is a good chance they might be the same species. The description of *S. pinnulatum* was based on one specimen, so the range of variability of the species is unknown, and it is impossible to decide definitely whether or not the *Te Vega* specimen belongs to the same species until more material is found.

Siboglinum spp.

Material examined

Seven empty tubes from *Te Vega* station 58 (*see* p. 2) (AM W. 6111, 6116, 6117).

Description

These empty pogonophore tubes can be separated into three distinct types:

(1) Segmented anterior end, regular brown rings; diameter 0.17 mm.

(2) No segmentation, wrinkled surface, narrow brown rings; diameter 0.115 mm (ant) tapering to 0.072 mm (post).

(3) No segmentation, wrinkled surface, rings smooth and colourless; diameter 0.14–0.17 mm.

Three species are represented and it is probable that they all belong to the genus *Siboglinum,* but they cannot be identified further without the animals

Family **LAMELLISABELLIDAE** Ushakov

Genus **LAMELLISABELLA** Ushakov

Lamellisabella pallida sp. nov.

Holotype

Male from *Te Vega* station 58 (see p. 2) (AM W. 6112).

Paratypes

Two immature specimens from the same station (AM W. 6113, 6115).

Description

None of the three specimens is fully mature, but the largest, a male containing a few spermatophores, is probably approaching the full-grown size for the species. A mature specimen might be expected to be slightly larger and might have more tentacles.

The tentacles are arranged side by side to form a cylinder with their pinnules inside. There are 16 tentacles in the largest specimen and 14 in one of the smaller ones. The flattened cephalic lobe is pointed at the tip (fig. 4, a, b). Behind the base of the tentacle crown the forepart is slightly flattened and there is a median groove along the antineural side, as far as the bridle. The bridle has thick, dark brown keels which are fused on the antineural side but well separate on the adneural side (fig. 4, a, b). The ratio of length to breadth for the forepart is about 5:1. The diaphragm between forepart and trunk can be seen by transparency, but there is no external demarcating groove. In the anterior part of the trunk low metameric papillae are rather widely spaced on paired lateral ridges, separated by a median groove (fig. 4, a). Each papilla is crowned by a cuticular plaque, the anterior border of which is a brown bar with inwardly projecting apodemes (fig. 4, de, e). The holotype has twelve pairs of these plaques, while the smaller specimens have six and nine pairs. Most of the plaques are about 55 μm in diameter and the range of size found is 45 to 60 μm. Behind the metameric region of the trunk is a non-metameric region with scattered small papillae, tipped by curved bars. There are two girdles, close together, with semidouble or double rows of platelets (fig. 1, c). The platelets are about 17 μm long (range 14–19 μm) with the anterior group of teeth smaller than the posterior group. The postannular region is not well preserved but can be seen to bear groups of at least two papillae at intervals, tipped by plaques about 45 μm in diameter. The opisthosoma is missing.

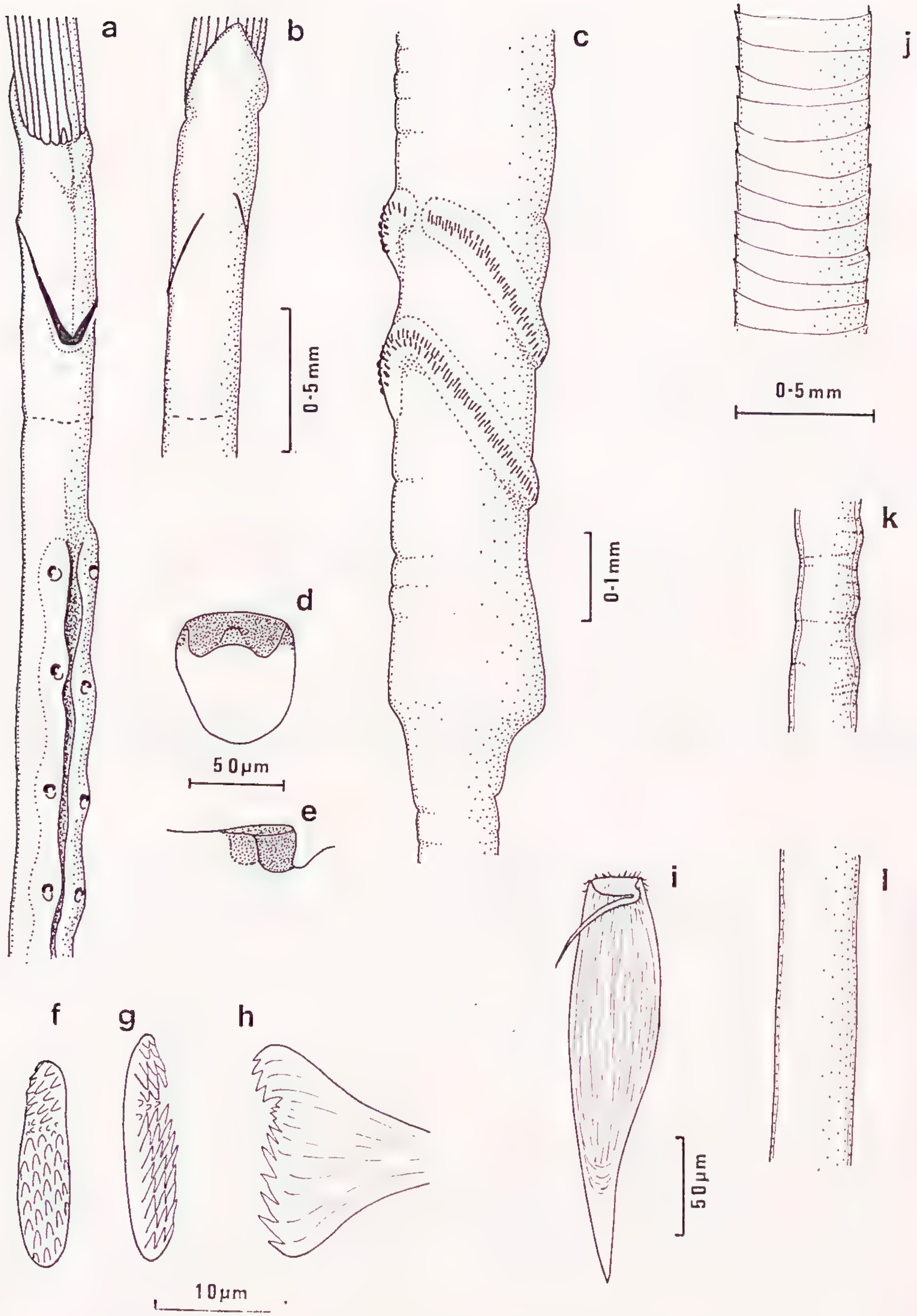

Figure 4.—*Lamellisabella pallida* sp. nov. a, forepart and anterior metameric region of trunk, antineural side; b, forepart, adneural side; c, girdle region; d, metameric plaque, face view; e, metameric plaque, side view; f, g, h, toothed platelets, face and side views; i, spermatophore; j, anterior part of tube; k, middle of tube; l, near posterior end of tube.

Spermatophores are present in the anterior parts of the sperm ducts, in the metameric region of the trunk. They are extremely thin plates, pointed at one end and with the filament base folded over at the other (fig. 4, i). The spermatozoa are arranged lengthwise and roughly parallel to one another. The length of spermatophore is 190 to 205 μm and the width is 48 μm.

The measurements of the animals are: length of tentacles 1.6 to 3.6 mm; length of forepart 0.85 to 1.4 mm; forepart diameter 0.16 to 0.30 mm; length of metameric region 1.0 to 5.0 mm; length of preannular region 4.7 mm in immature specimen but over 41 mm in holotype male.

The tubes are all pale yellow in the middle and colourless at the ends. All three have reformed the anterior end after being damaged. The anterior end is made up of very short, slightly overlapping segments, with thin colourless walls (fig. 4, j). The middle part has thicker, yellowish walls, which are rather corrugated and wrinkled but show no sign of rings or segments (fig. 4, k). The posterior end is wider than the middle and has smooth, colourless walls. The largest tube has an anterior diameter of 0.46 mm, middle diameter 0.23 mm and posterior diameter 0.32 mm; in the smallest tube these measurements are 0.32, 0.23 and 0.23 mm respectively.

Discussion

This new species of *Lamellisabella* is distinguished particularly by its small size, pale tube and small number of metameric plaques. *Lamellisabella johanssoni* Ivanov 1957 has about the same number of tentacles (18) but is considerably larger and has a dark brown to black tube with a funnel or funnels at the anterior end. *L. minuta* Ivanov 1963 has 10 tentacles and is about the same size as the new species but has at least 20 metameric plaques, of a smaller size (34 μm) and its bridle keels are not fused. In addition, *L. minuta* has a tube which is brown at the anterior end with well-marked overlapping funnels.

The name *pallida* denotes the pale colour of the tube and is derived from the Latin *pallidus* meaning pale or pale yellow.

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The Psocoptera (Insecta) Of Lord Howe Island

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Figures 1–54 Manuscript received 19th April, 1974

SUMMARY

This paper presents the first records of Psocoptera from Lord Howe Island.

Of the nine species included eight are new and *Caecilius quercus* Edwards is known from Tasmania.

INTRODUCTION

Nothing has been recorded on the Psocoptera of Lord Howe Island. Collecting at intervals since 1969 has yielded material of nine species of which eight are new and are described in this paper. The known species is recorded from Australia.

Discussion of the zoogeography of the Psocoptera of Lord Howe Island will be deferred until extensive material in collections from Australia, New Caledonia and other relevant areas has been worked.

Note: The IO/D ratio for species of Philotarsidae is measured by Pearman's method in order to allow comparison with other species in that family; in the remaining species Badonnel's method is used.

LIST OF SPECIES OF PSOCOPTERA FROM LORD HOWE ISLAND

Family **Lepidopsocidae**

Echmepteryx (*Loxopholia*) *howensis* sp. n.
Echmepteryx (*sens. lat.*) *anomala* sp. n.

Family **Caeciliidae**

Caecilius quercus Edwards

Family **Pseudocaeciliidae**

Pseudoscottiella fasciata sp. n.
Pseudoscotiella hollowayi sp. n.

Family **Elipsocidae**

Pentacladus marmoratus sp. n.
Spilopsocus parvus sp. n.

Family **Philotarsidae**

Aaroniella howensis sp. n.
Haplophallus tandus sp. n.

SYSTEMATIC ACCOUNT

Family **Lepidopsocidae**

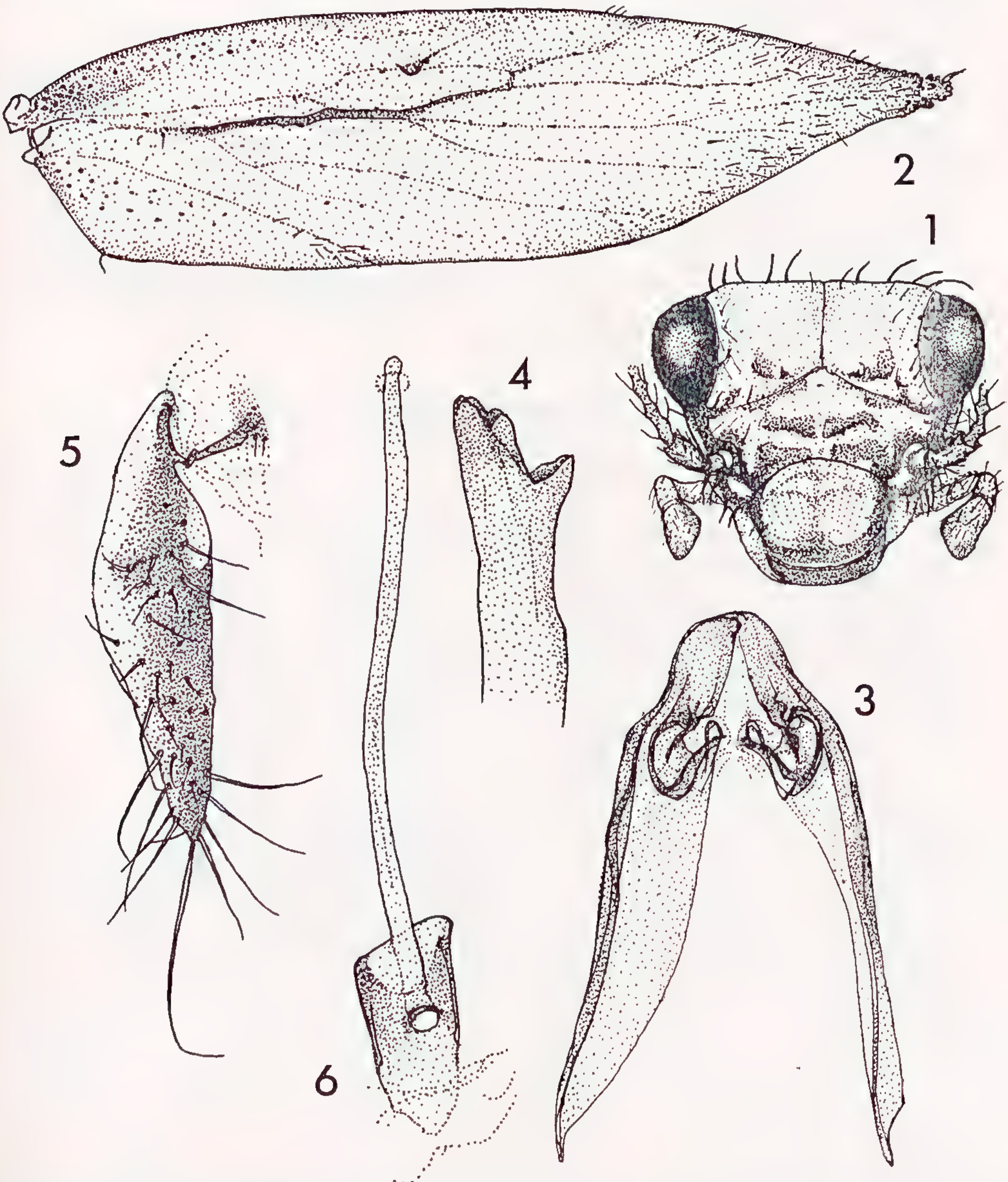
Echmepteryx (Loxopholia) howensis sp. n.

MALE

Coloration (in alcohol). Head pale buff with brown markings (fig. 1). Genae pale buff with an anterior brown stripe from eye to antenna base, a broader posterior stripe from eye to mandible. Antennae very pale brown. Eyes black. Ocelli absent, the position usually occupied indicated by a narrow dark brown circle. Maxillary palps pale buff, the distal segment only a little darker than others. Thorax pale buff with a longitudinal, dorso-lateral brown stripe. Femora pale buff; tibiae similar but with two brown bands; basal tarsal segment brown in basal sixth, remainder of tarsus pale. Fore wings (fig. 2) hyaline with veins pale except for m, $rs + m$, and rs as far as $r_1 - rs$ crossvein which are pale brown; the effect is thus of a hyaline wing with an incomplete longitudinal strengthening rod in the basal half of the wing. Abdomen pale with occasional lateral, segmentally arranged brown spots; terminal structures dark.

Morphology. Length of body: 2·9 mm. Vertex fairly sharp with a small notch at median epicranial suture. Eyes not quite reaching level of vertex. Ocelli absent. Lacinia as in female (fig. 4). Antennal segments short and fairly broad; f_1 four-fifths wide as long. Measurements of hind leg: F: 0·7 mm; T: 1·2 mm; t_1: 0·518 mm; t_2: 0·098 mm; t_3: 0·098 mm; rt: 5·2 : 1 : 1. Fore wings (fig. 2) with front and hind margins almost parallel for basal two-thirds,

then curving to meet at wing apex. Fore wing length: 2·4 mm; fore wing width: 0·68 mm. Basal section of *sc* absent, distal section indistinct. Veins *m*, *m* + *rs*, and *rs* as far as *r* − *rs* crossvein strongly developed; remaining veins somewhat evanescent; *rs* before joining *m* very faint. Scales of fore wing asymmetrical. Hind wing length: 2·08 mm; hind wing width: 0·48 mm. Epiproct simple, semicircular, setose. Paraproct with seven setae arising from rosette bases. Hypandrium mostly very well sclerotized, simple, a lightly sclerotized area occurs in the middle adjacent to the hind margin giving the impression that the hind margin is notched when seen under low power (x 10); strongly setose. Phallosome (fig. 3).



Figures 1–6.—*Echmepteryx* (*Loxopholia*) *howensis* sp. n. 1. ♂, head; 2. ♂, forewing; 3. ♂, phallosome; 4. ♀, lacinia; 5. ♀, gonapophyses; 6. ♀, entrance to spermatheca.

FEMALE

Coloration (in alcohol). As in male.

Morphology. Length of body: 2·9 mm. Lacinia (fig. 4). Measurements of hind leg as in male. Wing measurements as in male. Gonapophyses well sclerotized (fig. 5). Entrance to spermatheca (fig. 6). Paraproct as in male but with six setae arising from rosette bases.

MATERIAL EXAMINED

Lord Howe Island: 3 ♂ (including holotype), 1 ♀ (allotype), Transit Hill, 29.xi.1969; 1 ♂, Transit Hill, 23.ii.1971; 2 ♂, 1 ♀, "Blue Lagoon", 23.ii.1971; 8 ♂, 6 ♀, Lagoon Road, 28.xi.1969; 1 ♂, 1 ♀, Transit Hill Road, 27.xi.1969 (C. N. Smithers); 1 ♂, 1 ♀, Boat Harbour, 1.iii.1974 (G. A. Holloway).

Holotype, allotype and paratypes in the Australian Museum.

DISCUSSION

Echmepteryx howensis clearly belongs to the subgenus *Loxopholia* on venational features. It can be recognized from other species in that group by its distinctive facial pattern.

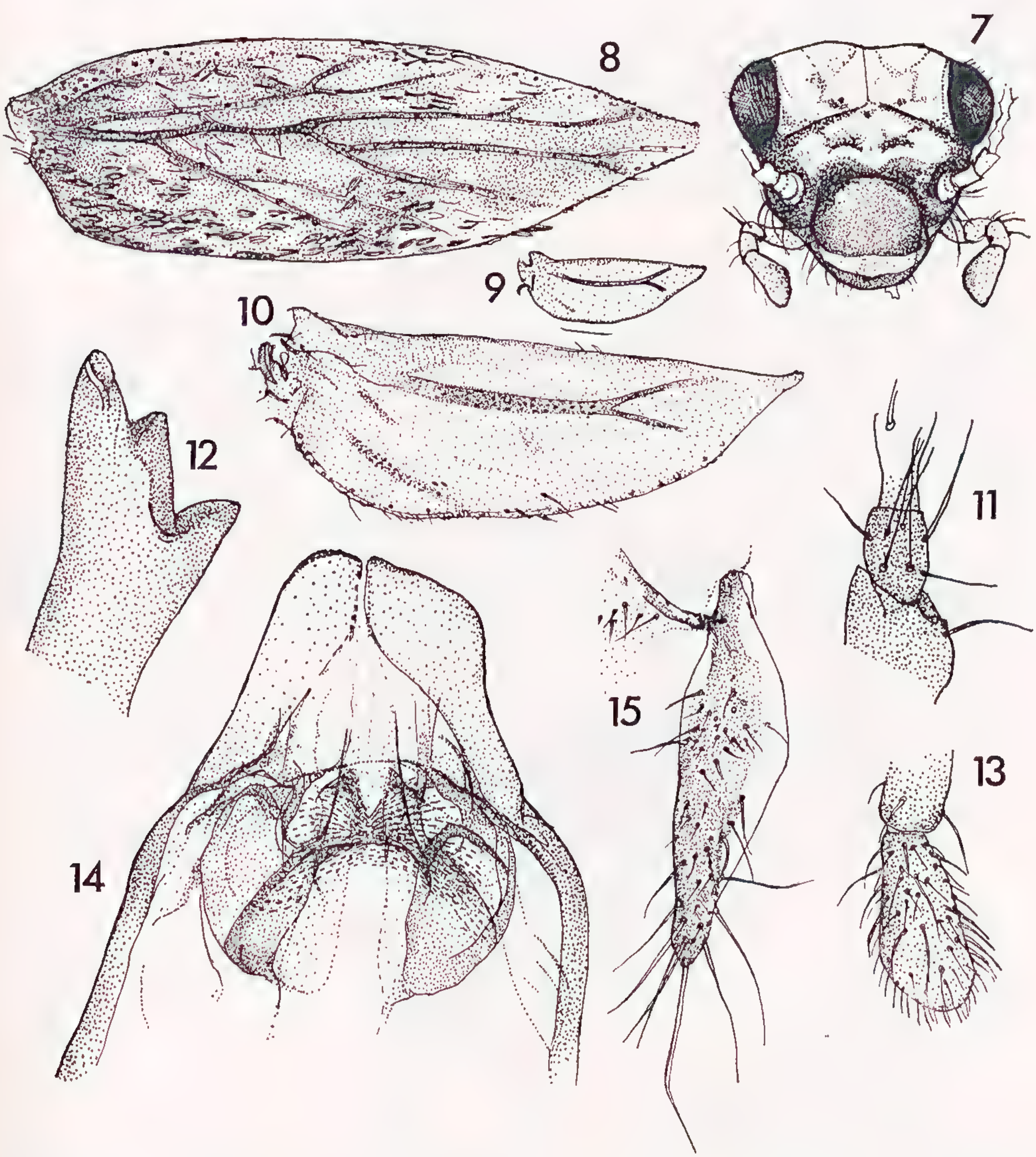
Echmepteryx anomala sp. n.

MALE

Coloration (in alcohol). Head pale buff, marked in various shades of brown (fig. 7). Labrum brown. Antennae pale brown. Maxillary palps coloured as head, fourth segment a little darker than others. Positions usually occupied by ocelli indicated by black spots. Eyes black. Thorax pale buff with lateral brown stripe. Fore wings (fig. 8) hyaline, tinged with pale brown, veins mostly brown. Hind wings (fig. 9 and fig. 10) reduced, hyaline. Legs pale with two transverse brown bands on tibiae and with short section at base of first tarsal segment brown. Abdomen pale with dark brown patches on paraprocts and epiproct; these spots are conspicuous against pale background of the apex of the abdomen.

Morphology. Length of body: 2·8 mm. Median epicranial suture very distinct although concolorous with vertex. Vertex fairly sharp. First flagellar segment (fig. 11). Antennae with at least 32 segments. Flagellar segments relatively long except first, which is short; fifth flagellar segment about 3·7 times long as wide. Eyes fairly large but not quite reaching level of vertex. Ocelli absent. Lacinia (fig. 12). Maxillary palp with apical segment rounded (fig. 13), broadened towards distal end. Measurements of hind leg: F: 0·658 mm; T: 1·092 mm; t_1: 0·420 mm; t_2: 0·084 mm; t_3: 0·084 mm; rt: 5 : 1 : 1. Tarsal claws with one strong preapical tooth and only traces of other preapical teeth. Fore wing length: 1·8 mm. Fore wings short (fig. 8), pointed, thickened and hardened in texture so that they are somewhat elytriform. Vein *sc* curving to meet *r* before origin of distal section of *sc* but weakly developed for most of its length. Vein *rs* fused with *m* for a length; *m*, $rs + m$ and free distal section of *rs* before bifurcation strongly developed; $r_1 - rs$ crossvein sometimes faint or absent. Veins bearing long easily detached setae; membrane bearing mostly asymmetrical scales. Hind wing length: 0·48 mm. Hind wing (fig. 9) (same scale as fore wing, and fig. 10 (enlarged) reduced to a small pointed membranous flap.

Veins reduced to a longitudinal fork ($r + m$?) and a very faint vein near wing base in posterior part of wing (cu_1?). Veins and margin with fairly strong setae. Epiproct simple. Hypandrium simple. Phallosome (fig. 14). Paraproct with a large posterior spine, setose, with six setae with rosette bases, adjacent to which arises a strong seta as long as the posterior spine.



Figures 7–15.—*Echmepteryx* (*s.l.*) *anomala* sp. n. 7. ♂, head; 8. ♂, forewing; 9. ♂, hindwing (scale as forewing); 10. ♂, hindwing (enlarged); 11. ♂, first flagellar segment; 12. ♂, lacinia 13. ♂, maxillary palp; 14. ♂, apex of phallosome; 15. ♀, gonapophyses.

FEMALE

Coloration (in alcohol). As in male.

Morphology. Length of body: 2·8 mm. General morphology as in male. Antennae with more than thirty-two segments. Lacinia as in male. Measurements of hind leg: F: 0·74 mm; T: 1·19 mm; t_1: 0·46 mm; t_2: 0·09 mm; t_3: 0·09 mm; rt: 5 : 1 : 1. Fore and hind wings as in male. Fore wing length: 2·0 mm. Hind wing length: 0·48 mm. Epiproct simple, sparsely setose. Paraproct as in male. Gonapophyses (fig. 15).

MATERIAL EXAMINED

Lord Howe Island: 1 ♂ (holotype), 2 ♀ (including allotype), Transit Hill Road, 27.xi.1969; 1 ♀, "Blue Lagoon", 23.vii.1971 (C. N. Smithers).
Holotype, allotype and paratypes in the Australian Museum.

DISCUSSION

Echmepteryx anomala is placed in the genus *Echmepteryx* Aaron with some reservation. The presence of scales clearly places it in either the Lepidopsocinae or Perientominae but the latter is excluded owing to the number of antennal segments exceeding twenty-four. Vein *rs* is forked in the fore wing, a characteristic of the tribe Lepidopsocini in which are included *Echmepteryx* Aaron, *Lepidopsocus* Enderlein and *Cyptophania* Banks. *E. anomala* has a 3-branched media in the fore wing (*Cyptophania* has a 2-branched media). Veins *rs* and r_1 are joined by a crossvein whereas in *Lepidopsocus* these veins are fused for a length. *E. anomala* does not conform to the characters of *Echmepteryx*, however, in lacking ocelli, in having long flagellar segments (a feature of the Perientominae) and in having strongly reduced hind wings. It is considered best to retain *E. anomala* in *Echmepteryx* until the species groups in the Lepidopsocinae have been more closely studied.

Roesler (1944) has provided a key to the subgenera of *Echmepteryx* but it is not possible to assign *E. anomala* to any of these as the key is based partly on hind wing venation; this is too reduced in *E. anomala* to be of value. The species is, therefore, assigned to *Echmepteryx* sens. lat.

Family **Caeciliidae**

Caecilius quercus Edwards

MATERIAL EXAMINED

Lord Howe Island: 1 ♂, 4 ♀, Transit Hill Road, 27–29.xi.1969 (C. N. Smithers).

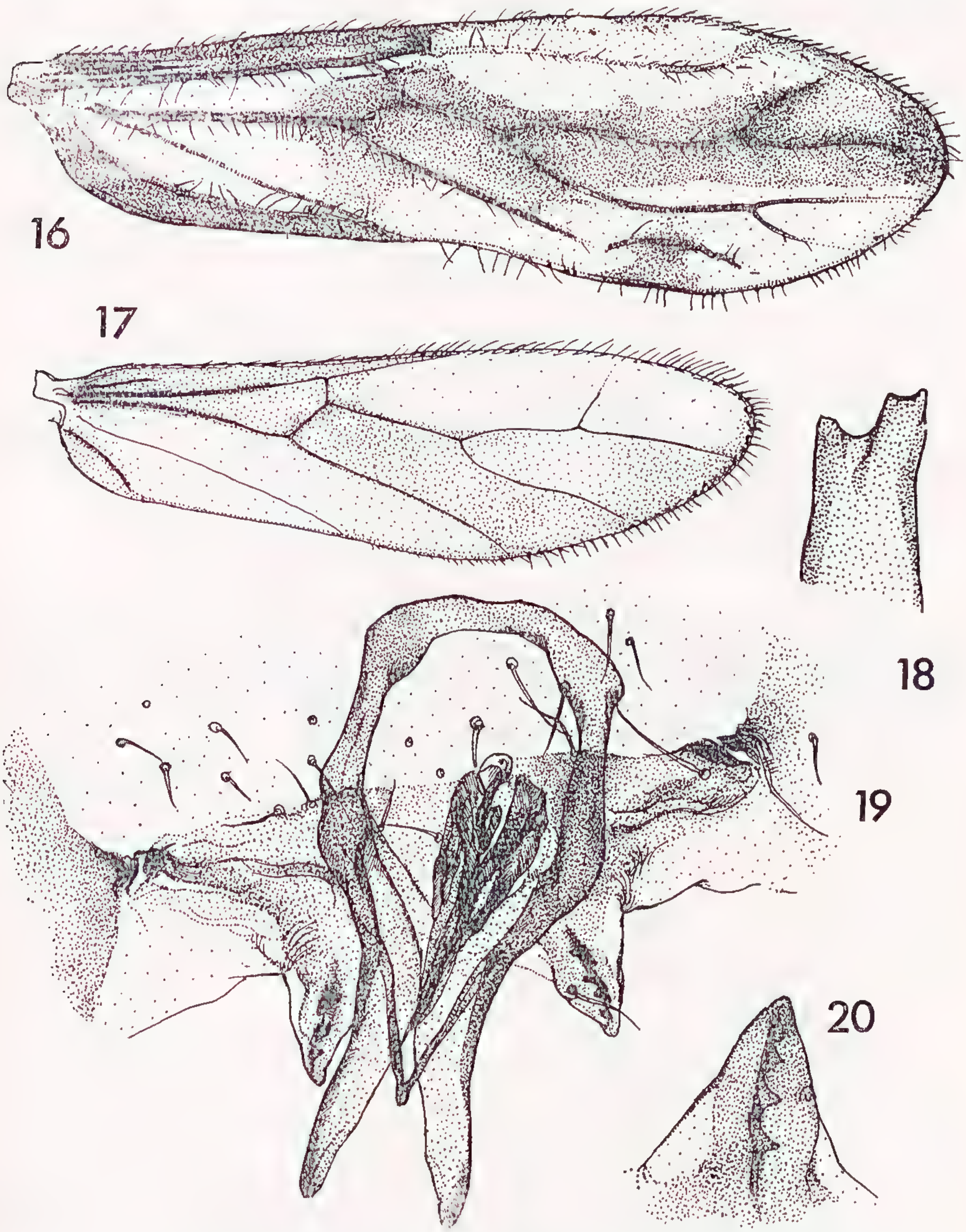
C. quercus is known from Tasmania.

Family Pseudocaeciliidae

Pseudoscottiella faiscata sp. n.

MALE

Coloration (in alcohol). Head pale brown with frons and a narrow area around ocellar triangle very pale. Labrum, maxillary palps and antennae as pale as frons. Eyes black. Ocelli bordered with black adjacent to each other. Seen from the side, thorax pale brown in upper half, very pale in lower, the junction



Figures 16–20.—*Pseudoscottiella fasciata* sp. n. 16. ♂, forewing; 17. ♂, hind wing; 18. ♂, lacinia; 19. ♂, hypandrium and phallosome; 20. ♂, posterior apophysis of hypandrium.

between the two areas marked by an irregular, much broken, dark brown band; thorax dorsally pale brown with a very pale median stripe. Fore and hind wings (fig. 16 and fig. 17) hyaline marked with brown. Abdomen pale except for a large, irregular black mark on each side near hind end.

Morphology. Length of body: 1·7 mm. Median epicranial suture distinct only on dark area of vertex; elsewhere indistinct. Vertex fairly flat. Postclypeus fairly flat. Lengths of flagellar segments: f_1: 0·49 mm; f_2: 0·25 mm. Eyes small. IO/D: 2·0; PO: 0·57. Lacinia (fig. 18). Measurements of hind leg: F: 0·434 mm; T: 0·826 mm; t_1: 0·210 mm; t_2: 0·084 mm; rt: 2·5 : 1; ct: 12, 0. Fore wing length: 2·4 mm; fore wing width: 0·68 mm. Fore wing (fig. 16) fairly narrow, pterostigma long and narrow; stigmapophysis very inconspicuous. Veins *rs* and *m* fused for a length, *rs* long before bifurcation; *m* 2-branched, *m* long and curved before bifurcation; cu_1 straight before areola postica. In hind wing r_{2+3} evanescent in distal half. Hind wing length: 1·8 mm; hind wing width: 0·52 mm. Epiproct simple, a small group of setae across distal area and a large sub-basal seta near each side. Paraprocts with a field of twelve setae with rosette bases. Phallosome and hypandrium (fig. 19); posterior apophyses with stout conical projections (fig. 20).

MATERIAL EXAMINED

Lord Howe Island: 1 ♂, (holotype), "Blue Lagoon", 23.ii.1971; 1 ♂, Lagoon Road, 28.xi.1969 (C. N. Smithers).

Holotype and paratype in the Australian Museum.

DISCUSSION

Pseudoscottiella fasciata can be distinguished from other species of the genus by its wing pattern. It is somewhat similar to the Micronesian species *Ps. pseudornatus* Thornton et al., *circularis* Thornton et al., and *ornatus* Thornton et al., but clear differences in extent of wing markings are apparent; the hypandrium and phallosome are also characteristic.

Pseudoscottiella hollowayi sp. n.

MALE

Coloration (in alcohol). As in *Pseudoscottiella fasciata.* Fore and hind wings (fig. 21 and fig. 22).

Morphology. Length of body not measurable owing to collapsed state of the abdomen. Eyes small, just reaching level of vertex. IO/D: 2·0; PO: 0·75. Measurements of hind leg: F: 0·686 mm; T: 1·106 mm; t_1: 0·266 mm; t_2: 0·126 mm; rt: 2·1 : 1; ct: 10, 0. Fore wing length: 3·3 mm; fore wing width: 0·88 mm. Fore wing long and narrow; veins *rs* and *m* fused for a long length. Pterostigma long and narrow; a few setae *on membrane* in distal part of cell R_3. Hind wing length: 2·6 mm; vein r_{2+3} hardly visible; *rs* and *m* fused for a long length. Hypandrium (fig. 23) very lightly sclerotized, the posterior lobes each bearing four conical protuberances (fig. 24). Phallosome (fig. 25).

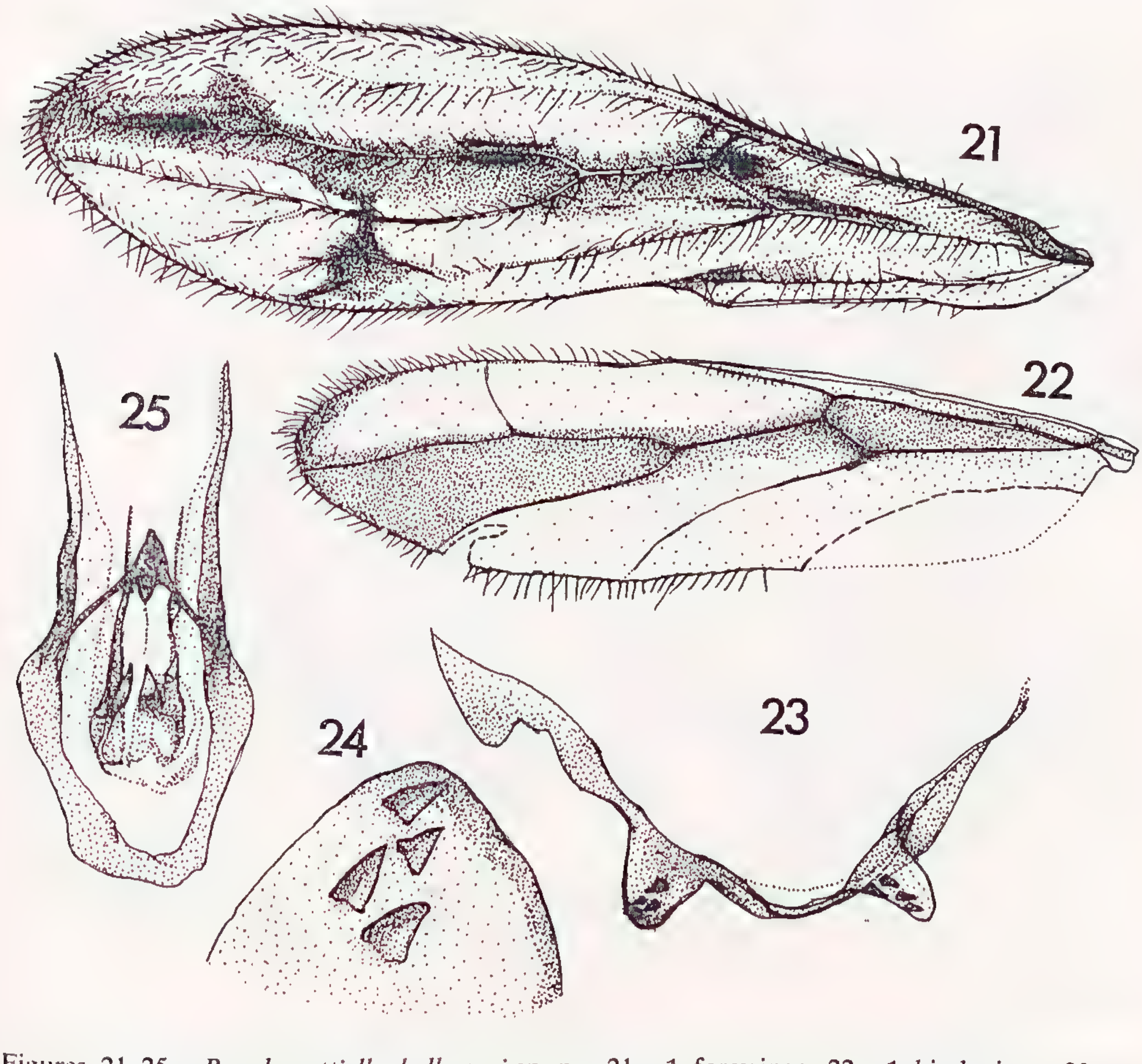
MATERIAL EXAMINED

Lord Howe Island: 1 ♂ (holotype), Mount Gower, 9.x.1971 (G. A. Holloway).

Holotype in the Australian Museum.

DISCUSSION

Pseudoscottiella hollowayi has a superficial resemblance to *Ps. fasciata* but differs considerably in size, being much larger, and in having setae on the membrane in the distal part of cell R_3. Other differences are to be found in the extent of wing pattern, the hypandrium and phallosome.



Figures 21–25.—*Pseudoscottiella hollowayi* sp. n. 21. ♂, forewing; 22. ♂, hind wing; 23. ♂, hypandrium; 24. ♂, posterior lobe of hypandrium; 25. ♂, phallosome.

Family **Elipsocidae**

Pentacladus marmoratus sp. n.

MALE

Coloration (in alcohol). Head pale buff with faint suggestion of a darker area adjacent to compound eyes and median epicranial suture. Thorax, abdomen and legs pale. Fore wings (fig. 26) hyaline marked in very pale brown. Eyes black. Ocelli margined in black along adjacent borders.

Morphology. Length of body: 2·3 mm. Median epicranial suture discernible but very faint. Vertex smoothly rounded with scattered fairly stout setae. Frons deep, setose as vertex. Postclypeus not very bulbous, setose but setae finer than on vertex. Antennae long and fine, nearly twice as long as fore wings. Lengths of flagellar segments: f_1: 0·89 mm; f_2: 0·39 mm. Eyes large, hemispherical, reaching level of vertex. IO/D: 1·6; PO: 1·0. Anterior ocellus much smaller than lateral ocelli. Lacinia (fig. 27). Thorax with fairly stout, scattered setae on dorsal surface. Femora in distal half with setae on upper surface and laterally in addition to the row of small evenly spaced, ventral setae. Measurements of the hind leg: F: 0·817 mm; T: 1·400 mm; t_1: 0·490 mm; t_2: 0·070 mm; t_3: 0·084 mm; rt: 7 : 1 : 1·2; ct: 24, 1, 0. Fore wing length: 2·92 mm; fore wing width: 1·08 mm. Veins *rs* and *m* meeting in a point or connected by an extremely short crossvein; the tall, apically pointed areola postica connected to *m* by a short crossvein; *m four-branched*. Marginal setae minute and sparse, arising from membrane near margin. Hind wing length: 2·08 mm; hind wing width: 0·64 mm. Vein *rs* straight from separation from *m* to bifurcation; *rs* and *m* fused for a fairly long length; cu_1 recurved near margin; a few minute marginal setae between r_{2+3} and r_4+_5. Epiproct simple, with setae near margin, a little more heavily sclerotized near base than in distal three-quarters. Paraproct with an ovoid trichobothrial field (fig. 28) with a large seta adjacent to it in addition to other setae. Hypandrium (fig. 29) posteriorly upturned with a curved lobe on each side. Phallosome (fig. 30).

FEMALE

Coloration (in alcohol). As in male but wing pattern a little darker.

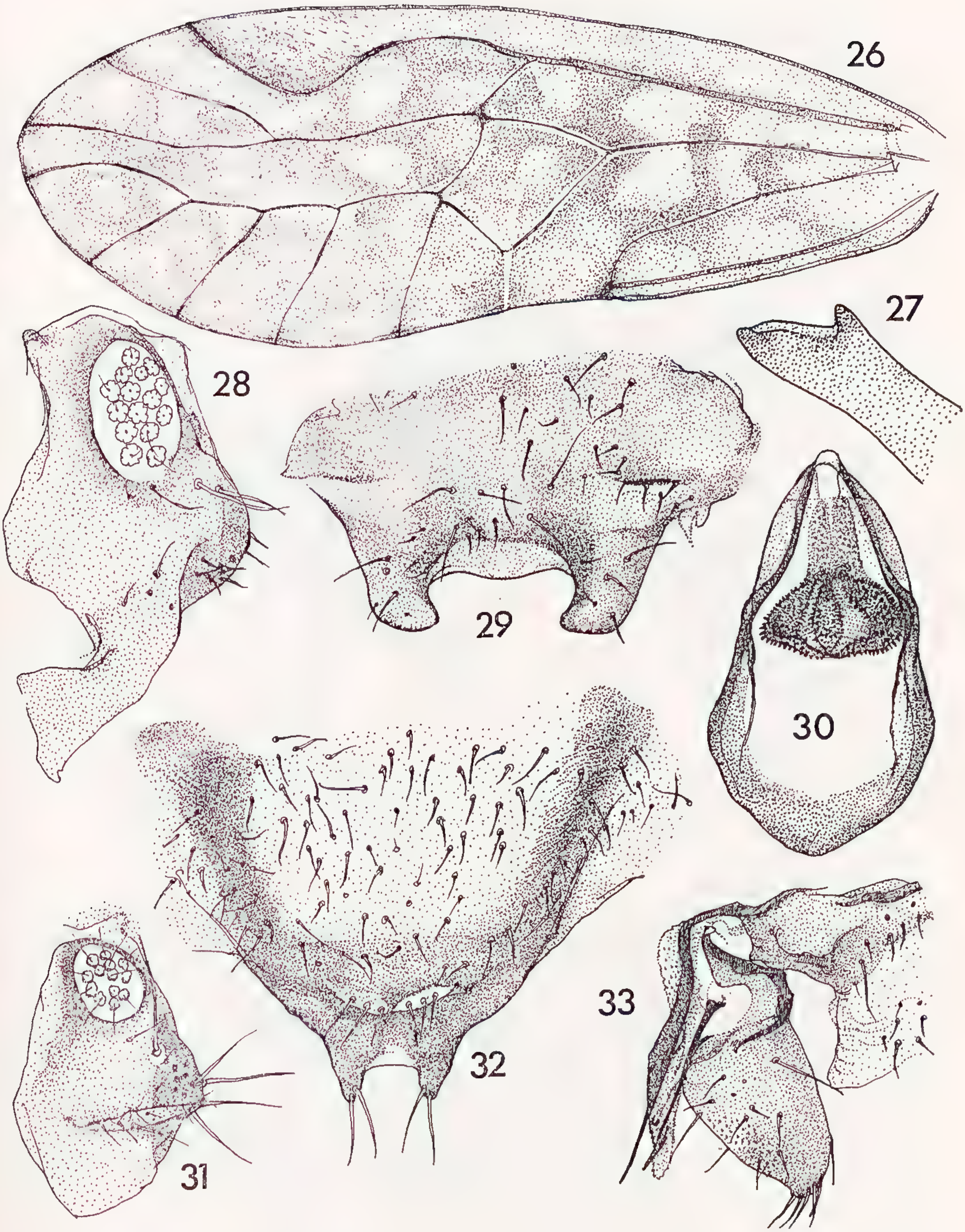
Morphology. Length of body: 2·9 mm. General morphology as in male. Eyes large, antennae nearly twice as long as fore wings. IO/D: 1·6; PO: 1·0. Measurements of hind leg: F: 0·84 mm; T: 1·52 mm; t_1: 0·546 mm; t_2: 0·070 mm; t_3: 0·098 mm; rt: 7·8 : 1 : 1·4; ct: 24, 1, 0. Fore wing length: 3·10 mm; fore wing width: 1·12 mm. Venation and setae as in male. Hind wing length: 2·20 mm; hind wing width: 0·72 mm. Venation as in male. Paraproct (fig. 31) with circular field of trichobothria, large adjacent seta and long setae on posterior margin. Subgenital plate (fig. 32). Gonapophyses (fig. 33).

MATERIAL EXAMINED

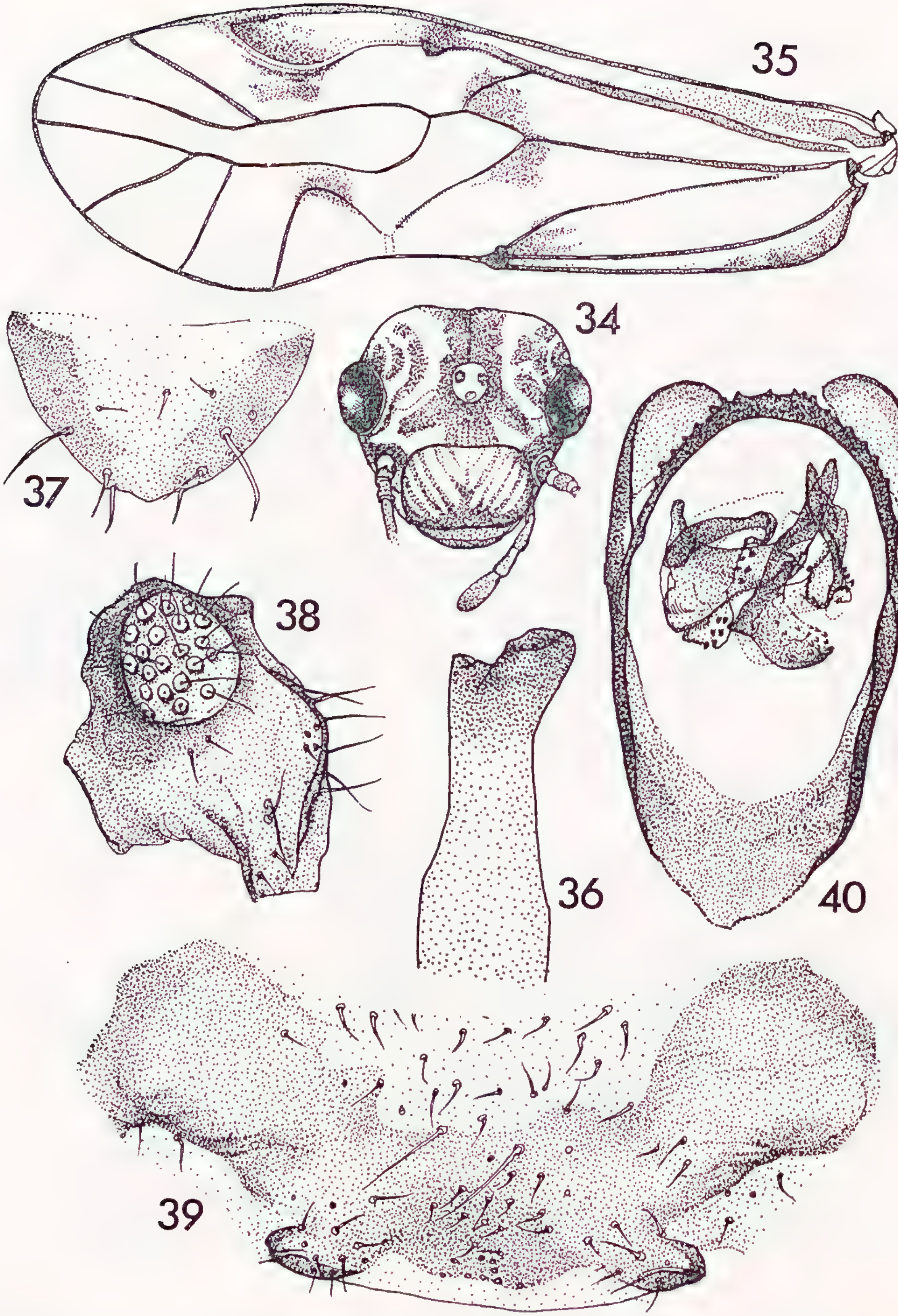
Lord Howe Island: 1 ♂ (holotype), 1 ♀ (allotype), 1 nymph, Lagoon Road, 28.xi.1969 (C. N. Smithers). Holotype and allotype in the Australian Museum.

DISCUSSION

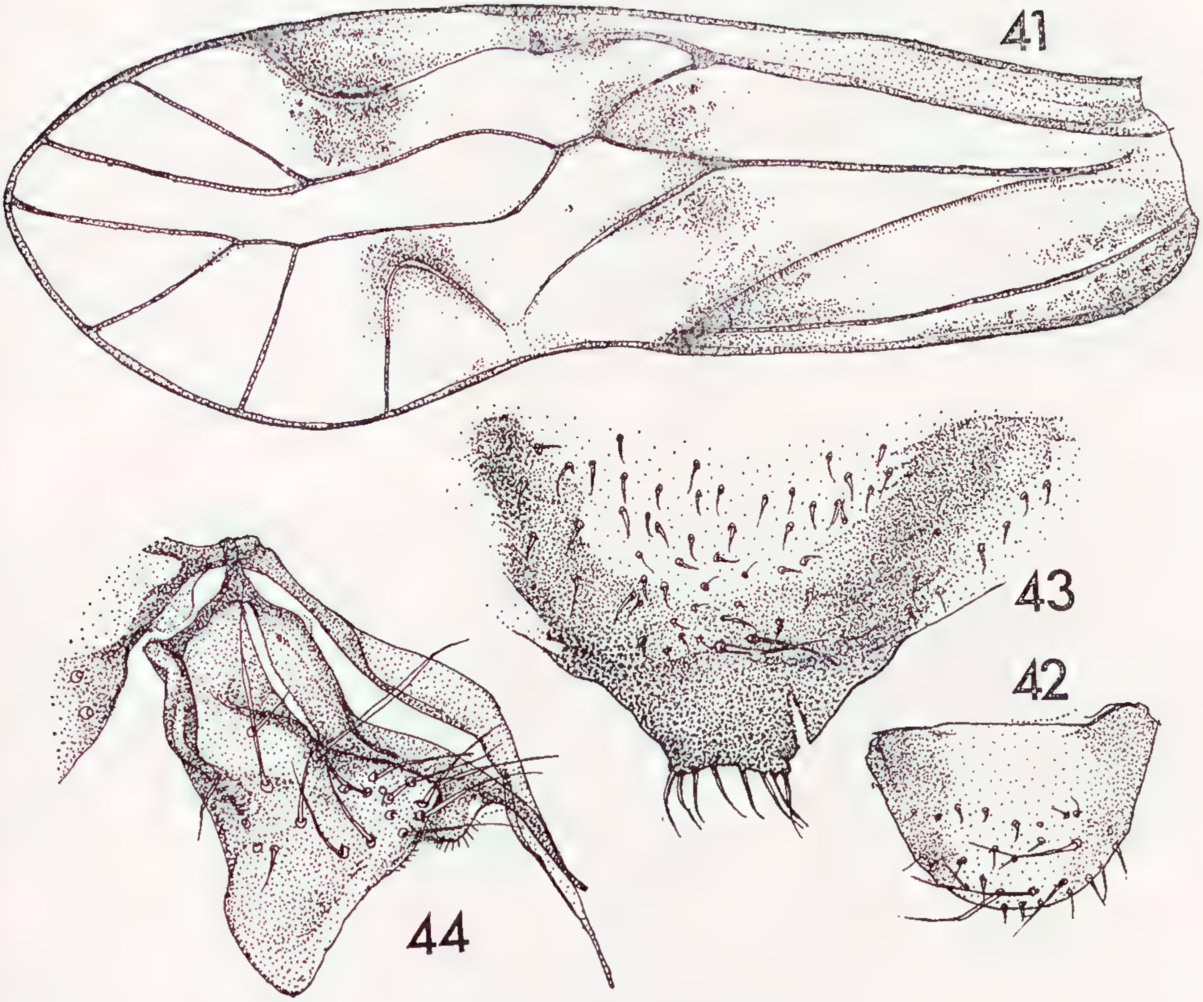
Pentacladus marmoratus differs conspicuously from *P. eucalypti* Enderlein, the only other member of the genus, in wing pattern and is easily distinguished on this feature alone.



Figures 26–33.—*Pentacladus marmoratus* sp. n. 26. ♂, forewing; 27. ♂, lacinia; 28. ♂, paraproct; 29. ♂, hypandrium; 30. ♂, phallosome; 31. ♀, paraproct; 32. ♀, subgenita plate; 33. ♀, gonapophyses.



Figures 34–44 (above and on opposite page).—*Spilopsocus parvus* sp. n. 34. ♂, head; 35. ♂, fore wing; 36. ♂, lacinia; 37. ♂, epiproct; 38. ♂, paraproct; 39. ♂, hypandrium; 40. ♂, phallosome; 41. ♀, fore wing; 42. ♀, epiproct; 43. ♀, subgenital plate; 44. ♀, gonapophyses.



Spilopsocus parvus sp. n.

MALE

Coloration (in alcohol). Head pale buff with brown markings (fig. 34). Median epicranial suture dark brown. Postclypeus with anteriorly converging stripes. Labrum brown. Genae pale except for brown area immediately below compound eye. Antennae with scape, pedicel and basal two-thirds of first flagellar segment brown, remainder of flagellum dark brown. Eyes purplish. Area around ocelli pale buff but ocelli with purplish backing. Maxillary palps brown. Dorsal lobes of mesothorax brown, pale adjacent to sutures; antedorsum brown, partly divided in the middle by a longitudinal pale stripe and pale near sutures. Legs pale brown except for distal parts of tibia and tarsi which are darker. Fore wings (fig. 35) hyaline marked with brown. Abdomen pale with incomplete, irregular segmental bands of brown.

Morphology. Length of body: 1·7 mm. Median epicranial suture distinct, anterior arms evanescent. Vertex gently rounded, glabrous. Lengths of flagellar segments: f_1: 0·546 mm; f_2: 0·322 mm. Antennae a little longer than fore wings. Eyes fairly large, not reaching level of vertex. IO/D: 1·80; PO: 0·71. Lacinia (fig. 36). Measurements of hind leg: F: 0·448 mm; T: 0·896 mm;

t_1: 0·266 mm; t_2: 0·042 mm; t_3: 0·070 mm; rt: 6·3 : 1 : 1·2; ct: 14, 1, 0. Tibia broadens a little in distal quarter, which corresponds to the darker sections of the tibia. Fore wing length: 2·24 mm; fore wing width: 0·76 mm. Fore wing marginal setae very small and fine; bifurcation of *rs* basad of origin of m_3; areola postica tall and smoothly arched. Hind wing with cu_1 strongly recurved near wing margin. A few fine, short setae on margin between r_{2+3} and r_{4+5}. Epiproct (fig. 37) almost semicircular, a little more heavily sclerotized laterally than mesially, sparsely setose. Paraproct (fig. 38) with an almost circular trichobothrial field and a strongly sclerotized, arched dorsal ridge. Hypandrium (fig. 39) with almost straight hind margin and a small lateral lobe on each side. Phallosome (fig. 40).

FEMALE

Coloration (in alcohol). Similar to male but wing pattern a little more extensive (fig. 41).

Morphology. Length of body: 2·0 mm. General morphology as in male. Antennae more slender and eyes smaller, antennae shorter than fore wing. Length of flagellar segments: f_1: 0·420 mm; f_2: 0·266 mm. IO/D: 2·3; PO: 0·83. Measurements of hind leg: F: 0·434 mm; T: 0·910 mm; t_1: 0·252 mm; t_2: 0·042 mm; t_3: 0·070 mm; rt: 6·0 : 1 : 1·6; ct: 14, 1, 0. Tibiae distally broadened as in male. Fore wing length: 2·36 mm; fore wing width: 0·84 mm. Wing characteristics as in male but *rs* bifurcation nearly opposite origin of m_3. Hind wing length: 1·92 mm; hind wing width: 0·64 mm. Epiproct (fig. 42). Subgenital plate (fig. 43) with a poorly developed median posterior lobe, the posterior margin of which bears eight setae; preapical row of setae reduced to two strong setae near midline. Gonapophyses (fig. 41).

MATERIAL EXAMINED

Lord Howe Island: 3 ♂ (including holotype), 1 ♀ (allotype), Lagoon Road, 28.xi.1969; 2 ♂, Transit Hill, 23.ii.1971; 2 ♀, Transit Hill Road, 27–29.xi.1969 (C. N. Smithers); 1 ♀, Ned's Beach, 22.ii.1971 (D. K. McAlpine).

Holotype, allotype and paratypes in the Australian Museum.

DISCUSSION

Spilopsocus parvus can be distinguished from other members of the genus (other than *S. stigmaticus* (Tillyard) from New Zealand) by its wing pattern. Although clearly closely related to *S. stigmaticus* it is much smaller and differs in details of the form of the complex sclerifications of the penial bulb in the male and in the form of the gonapophyses in the female.

Family **Philotarsidae**

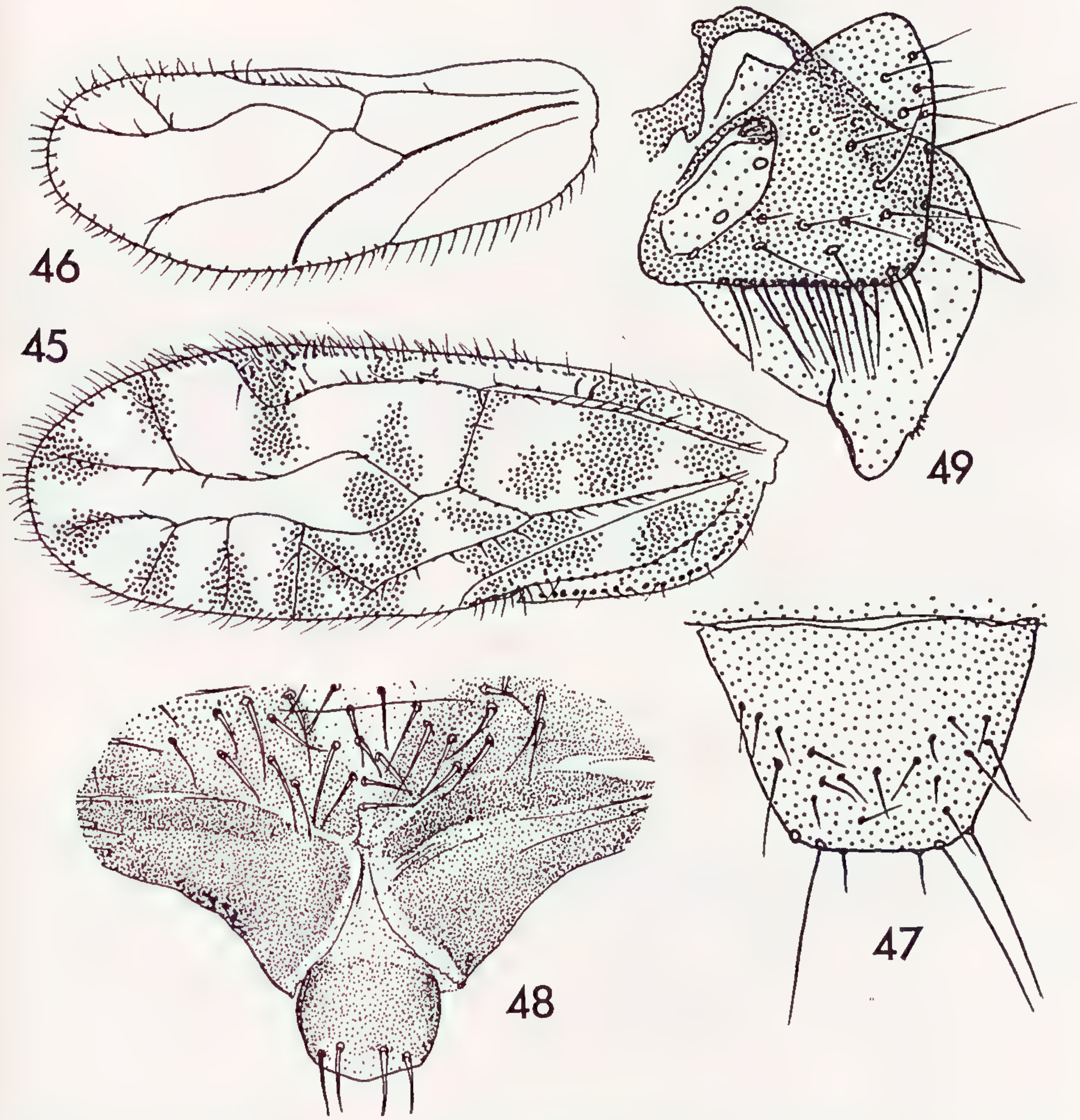
Aaroniella howensis sp. n.

FEMALE

Coloration (after 18 years on pin, then softening and removal into alcohol): Cuticle generally transparent. Brown pigment clearly visible on vertex (usual pattern), medial stirrup-mark on frons, and clypeal striae on middle third of clypeus. Apical segment of maxillary palp brown; antennae brown, segments with distinct pale apices. Mesothoracic antedorsum brown with pale median line,

dorsal lobes brown except at edges of sclerites. Metathoracic terga pale. Thoracic pleura and legs pale except apices of tibia brown, tarsal segments brown. Fore wing (fig. 45) with distinct dark brown markings, setae not sited on brown spots. Hind wing (fig. 46) hyaline, vein cu_1 dark brown. Abdomen pale.

Morphology. Length of body: 2·45 mm; IO/D (Pearman): 6·2.:1 Antennae broken, but f_1: 0·29 mm; f_2: 0·12 mm; $f_1 : f_2$ = 2·42:1. Measurements of hind leg: F: 0·55 mm; T: 0·84 mm; t_1: 0·12 mm; t_2: 0·06 mm; t_3: 0·06 mm; rt: 2 : 1 : 1; t_1 unusually short; ct: 0; claw with a very small preapical tooth. Fore wing length: 2·40 mm. Areola postica connected to vein *m* by a crossvein in both wings, basal section of *rs* very long and unusually transverse, vein cu_2 bare; fore wing smoothly rounded, evidence of incipient brachyptery in conformation of apical veins but wings extend well beyond abdomen, evidently held almost horizontally in repose. Hind wing length: 2·02 mm. Setae on veins r_1: 11; *rs*: 0; r_{2+3}: 3;



Figures 45 49.—*Aaroniella howensis* sp. n. 45. ♀, fore wing; 46. ♀, hind wing; 47. ♀, epiproct; 48. ♀, subgenital plate; 49. ♀, gonapophyses.

r_4+_5: 3; m: 2; cu_1: 1. Epiproct (fig. 47) squarish, paraproct with a field of 14 trichobothria and one seta not in rosette socket. Subgenital plate (fig. 48) with a pair of very long setae basally, apically tripartite, apical lobe bearing 4 marginal setae; gonapophyses (fig. 49); ventral valve with fleshy apical lobe; dorsal valve bluntly pointed, no prominent subapical spine but a subapical spiny area; outer valve subtriangular, heavily setose.

MATERIAL EXAMINED

Lord Howe Island: 1 ♀ (holotype), 5.xii.1955 (S. J. Paramonov and Z. Liepa).

Holotype in the Australian National Insect Collection.

DISCUSSION

This species is unusual in several respects, but is placed in *Aaroniella* Mockford since it agrees with the type species *A. maculosa* (Aaron) in the following characters: antennal segments with white apices, fore wings smoothly rounded, vein cu_2 in fore wing bare, outer valve of gonapophyses triangular, ventral valve with fleshy apical lobe, subgenital plate apically tripartite. It differs from the type species, and agrees with *A. rawlingsi* Smithers (New Zealand), *A. pallida* New (Australia), and *A. trukensis* Thornton et al., and *A. gressitti* Thornton et al. (Micronesia) in that the apical sclerite of the subgenital plate is not bare, but carries 4 marginal setae. This character is common to southern hemisphere species of the genus. *A. galapagensis* Thornton and Woo (Galapagos), like *A. howensis*, does not have the fore wing setae sited on dark spots, but the dorsal valve shape is unusual for *Aaroniella*. If *A. howensis* is a typical member of the south Pacific section of the genus, one can predict that if and when a male is found, the phallosome will be found to lack distinct separate internal sclerites.

The pattern of pigmentation of the fore wings is quite distinctive, as is the remarkable connection of the areola postica with the media. With but a single specimen, it is impossible to say whether this latter character is a feature of the species, or variable with incipient brachyptery.

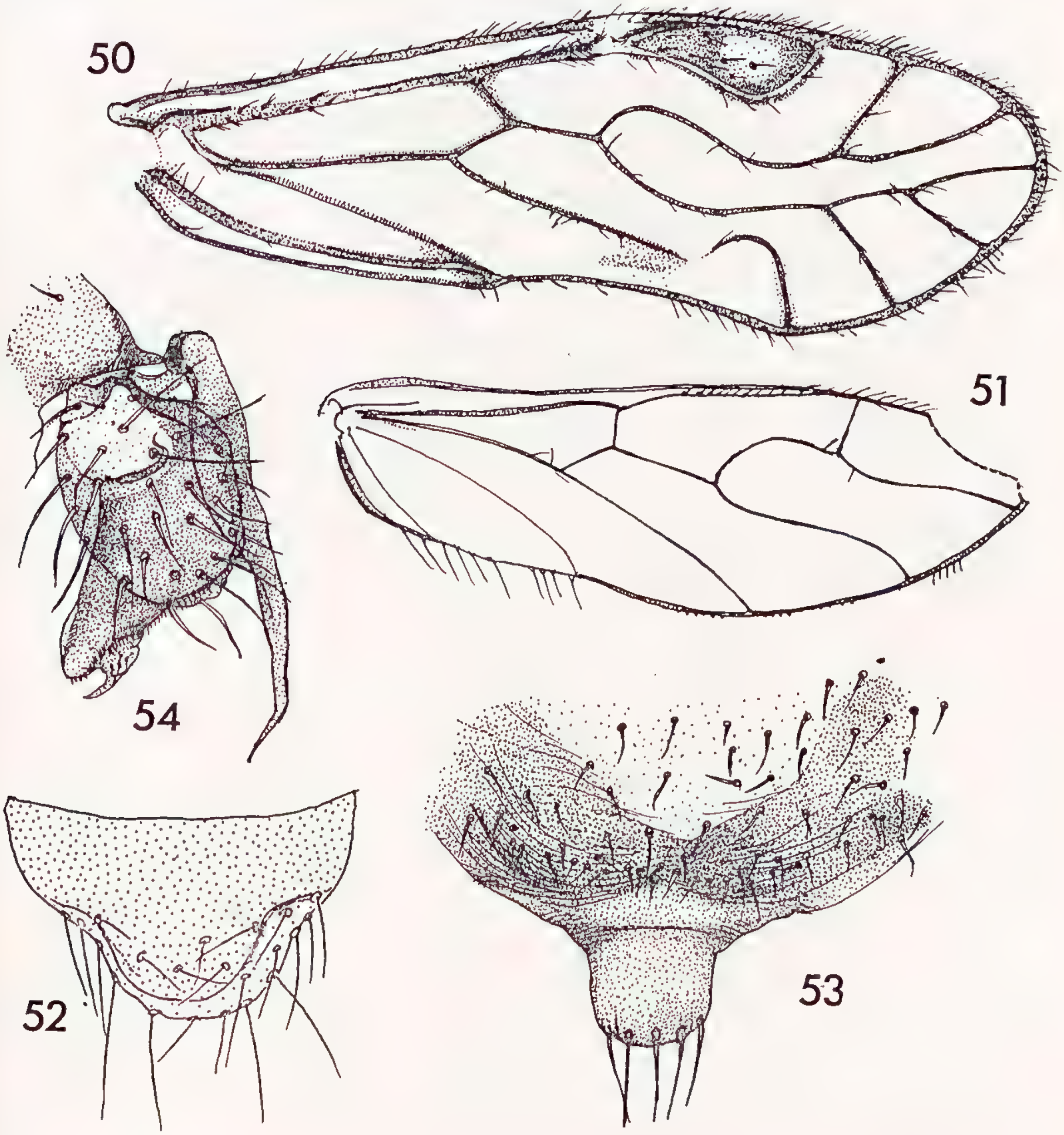
Species of *Aaroniella* have not been found on Norfolk Island nor on New Caledonia.

Haplophallus tandus sp. n.

FEMALE

Coloration. Head cream, usual markings on vertex brown. Frons with a pair of dark brown bars on each side of a rounded brown median mark. Gena cream, with a small brown patch at anterior corner. Clypeus with striae evident posteriorly, anterior third with a pair of large rounded cream areas separated almost to anterior edge by a brown mark. Eyes black, ocelli pale, ringed with black. Legs: coxa brown, femur cream with 2 brown bands (pro- and mesothoracic legs) or one (hind leg), tibia cream with three brown bands, one near each end and one midway, tarsi brown. Fore wing (fig. 50), no cloudiness in apical cells, pterostigma "windowed". Hind wing (fig. 51) with faint fuscous area in cell R_1. Thoracic terga brown, cream along the sutures, a cream mid-line. Abdomen with wide grey-brown granulated annulations dorsally, narrower ventrally.

Morphology. Length of body: 2·50 mm. IO/D (Pearman): 3·0 : 1. Median epicranial suture distinct. Length of flagellar segments: f_1: 0·24 mm; f_2: 0·15 mm; f_1: f_2 = 1·60. Hind leg measurements: F: 0·33 mm; T: 0·68 mm; t_1: 0·19 mm; t_2: 0·04 mm; t_3: 0·04 mm; rt: 4·75 : 1 : 1; ct: 13. Fore wing length: 2·35 mm. Hind wing length: 1·85 mm. Setae on hind wing veins: r_1: 7; rs: 0; r_{2+3}: 0; r_{4+5}: 11; m: 9; cu_1: 3. Epiproct (fig. 52) rounded apically, with scattered setae. Epiproct evidently with a setose flap much as in species of *Zealandopsocus* Tillyard. Paraproct simple with circular field of 15 trichobothria, and 2 not in rosette sockets. Subgenital plate (fig. 53) with a distinct apical lobe bearing 5 marginal setae and a distinct bare subapical sclerite. Gonapophyses (fig. 54) dorsal valve with curved pointed subapical spine bearing a group of short, fine, setae subapically; outer valve oval, with long setae.



Figures 50–54.—*Haplophallus tandus* sp. n. 50. ♀, fore wing; 51. ♀, hind wing; 52. ♀, epiproct; 53. ♀, subgenital plate; 54. ♀, gonapophyses.

MATERIAL EXAMINED

Lord Howe Island: 1 ♀ (holotype), Transit Hill Road, 29.xi.1969 (C. N. Smithers).

Holotype in the Australian Museum.

DISCUSSION

Haplophallus tandus is similar to *H. emmus* Smithers and Thornton (Norfolk Island) and *H. trepticus* Thornton and Smithers (New Caledonia) in having vein cu_1 in the hind wing setose and vein cu_2 in the fore wing bare, the subgenital plate apical lobe distinctly marked off from the rest of the plate with a single bare subapical sclerite, and in the general shape of the dorsal valve of the female gonapophyses. The three species form a small group related to the widespread *orientalis* group of six species which has representatives in New Zealand, Micronesia, the Oriental Region, Seychelles and Africa.

The head pattern of *H. tandus* distinguishes it from *H. emmus* and *H. trepticus*, neither of which possess the two pairs of dark brown bars antero-lateral to the ocelli. *H. trepticus* has the large pale semicircular areas on the anterior of the clypeus, but also has a fairly wide median area posteriorly that is devoid of striae; the clypeus of *H. tandus* like that of *H. emmus*, lacks the pale median area. *H. emmus* also lacks the large pale circular areas anteriorly. In *H. trepticus* the ocellar area is bounded by a distinct thin brown line of pigment; this is absent from *H. tandus* and *H. emmus*. In fore wing pattern also, *H. tandus* is a mosaic of parts of the patterns of *H. emmus* and *H. trepticus*. Like *H. emmus* the apical cells are hyaline, and like *H. trepticus* the pterostigma is windowed hyaline. The subgenital plate of *H. tandus* is very similar to that of *H. trepticus*, whereas the gonapophyses are more similar to those of *H. emmus*. The outer valve is oval, not circular, and the dorsal valve subapical spine is curved and sharply pointed, rather than blunt. The setose flap of the female epiproct is unusual in species of *Haplophallus*, being found also in *H. emmus*. This character is a feature of *Zelandopsocus* species; the character appears outside *Zelandopsocus* also in New Zealand species of *Aaroniella*.

TABLE 1

Comparison of eight characters in three species of *Haplophallus*

	trepticus (N.C.)	*emmus* (N.I.)	*tandus* (L.H.I.)
1. 2 prs dark brown transverse bars antero-lateral to ocelli	absent	absent	present
2. Ocellar area brown boundary ..	present	absent	absent
3. Clypeus posterior median cream area	present	absent	absent
4. Clypeus anterior large cream areas circular	present	absent	present
5. Pterostigma pattern	windowed	not	windowed
6. Dorsal valve subapical spine ..	blunt	pointed	pointed
7. Outer valve	round	oval	oval
8. Subgenital plate apical lobe setae	3–5	2	5

Of the eight characters considered in Table 1, two are shared by all three species. *H. tandus* and *H. trepticus* have two characters in common; *H. emmus* and *H. trepticus* have three in common. Six of the characters are shared by *H. tandus* and *H. emmus*. It seems likely that both the Lord Howe and Norfolk species have evolved from the New Caledonian *H. trepticus*, and possibly through a single daughter species.

ACKNOWLEDGEMENTS

We would like to thank the Lord Howe Island Board and the Trustees of the Australian Museum for the financial support which made collecting possible and to record thanks to the residents on the island who assisted in a great many ways to facilitate field work. Miss Justine O'Regan prepared most of the illustrations to this paper.

REFERENCE

Roesler, R., 1944. Die Gattungen der Copeognathen. *Stettin. ent. Ztg.*, 105: 117–166.

GUIDE TO AUTHORS OF AUSTRALIAN MUSEUM MEMOIRS AND RECORDS

1. Scope

The Australian Museum publishes in its Records and Memoirs the results of original research dealing with material in its collections or with subjects of interest to the Museum, including taxonomic and general zoology, palaeontology, anthropology, mineralogy, and related fields. Contributions of well above average length are published in the Memoirs.

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Manuscripts should be sent to the Editor, Records and Memoirs of the Australian Museum. The original and one copy of the text must be submitted; the author should retain one copy. Original artwork should be retained by the author pending final acceptance of the paper for publication; two copies of the illustrations must be submitted with the text. Alternatively, good-quality photographic reproductions of the original artwork may be submitted. Papers will be reviewed by at least one referee before being considered for final acceptance. They must be in final form for publication so that changes at proof stage will be as few as possible.

The manuscript—including tables, headings, indices, legends to figures, and literature cited—must be clearly and neatly typewritten, double-spaced, on one side of bond or other good quality paper, and with 3 cm margins all round. Pages should be numbered consecutively. Tables and legends to illustrations should be on separate pages at the end of the manuscript. The entire manuscript should be securely fastened together.

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Papers should be arranged as follows:

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(ii) The author's name and professional address.

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(iv) A list of contents may be included if the paper is very long.

(v) Introduction.

(vi) The main text of the paper.

(vii) Acknowledgments.

(viii) References (see below).

(ix) Index (in the case of very long papers).

The approximate position of tables and figures should be indicated in pencil at the left-hand margin.

Only the names of genera and species should be underlined. Unless indicated elsewhere in the text, or where nomenclature follows a generally accepted standard (which should be cited), the authority should be cited when any specific name is used for the first time.

In taxonomic papers the short form (taxon, author, date, page) should be used in synonymies and the full reference taken to the end of the paper. In synonymies a period and dash (.—) should separate the name of the taxon and the name of the author except in the case of the reference to the original description. Where new species are described the location of the type material must be indicated and Article 73 and associated recommendations of the International Code of Zoological Nomenclature should be followed. Dichotomous keys with contrasting parts of couplets adjacent to each other are recommended. In these only the first part of the couplet should be numbered and the beginning of the second indicated with a dash at the left-hand margin. Keys must not use serially indented couplets.

4. Tables

Tables should be typed on separate sheets and numbered in arabic numerals. Headings should be self-explanatory. Material in the text should not duplicate that in the tables. Duplication of information in tables and graphs should generally be avoided.

Tables should have the very minimum number of horizontal and vertical lines. Very large or complex tables should be submitted in a form suitable for direct preparation of line blocks; such tables should not exceed 14 cm x 20 cm and numbers and letters should be as large as practicable.

A REVISION OF THE GOBIID FISH GENUS *KELLOGGELLA*

By Douglass F. Hoese

Plates 1–3, Figures 1–3.

Manuscript received, 14th March, 1974.
Manuscript revised, 20th June, 1974.

SUMMARY

The genus *Kelloggella* is diagnosed on the basis of the four known species. The nominal genera *Itbaya, Atuona,* and *Agunia* are placed in the synonomy of *Kelloggella.* The four species are compared and *K. centralis* is described as new.

INTRODUCTION

The four goby species of the genus *Kelloggella* are among the smallest fishes known. The largest specimen recorded is 26 mm standard length. Because of the small size of the species, many of the features characterizing the genus and those separating the species have been overlooked or incorrectly reported. This situation has lead to the description of five species placed in five different genera. The discovery of a new species from Eniwetok and Rarotonga led to the present revision.

Jenkins (1903) described the first known species, an Hawaiian species, in the New World genus *Enypnias,* as *E. oligolepis.* The generic placement was based on the alleged occurrence of scales on the posterior part of the body. Examination of recently collected material and the original material has failed to reveal any scales or scale pockets. Jordan and Seale (1906) described *Kelloggella cardinalis* from Samoa as the type species of *Kelloggella.* They also allocated *E. oligolepis* to *Kelloggella.* The genus was characterized as having a naked body and an elongate head and body, but no mention was made of the tricuspid teeth characteristic of the genus. Bean and Weed (1912) later reported the tricuspid teeth in *Kelloggella.* Herre (1927) redescribed *K. cardinalis* from the Philippines, as a new species and genus, *Itbaya nuda.* The genus *Itbaya* was diagnosed as having tricuspid teeth in the lower jaw only and a naked body. The genus was also characterized as having an interorbital crest, which is developed only in large individuals and is accentuated by dehydration upon preservation. Herre (1935) subsequently described *Atouna tricuspidata* from the Marquesas with tricuspid teeth in both jows and the naked body. He compared the genus with *Itbaya* separating the two on the basis of the dentition. Fowler (1946) described the fourth genus *Agunia,* with *A. quindecimfasciata* as the type species, virtually identical with *K. oligolepis.* Fowler incorrectly reported four dorsal spines, rather than six. He separated *Agunia* from *Itbaya* on the basis of the deeper body, longer pectoral fins, and barred coloration of *Agunia.* He noted the tricuspid teeth, but made no comparison with *K. oligolepis.* Undoubtedly much of the confusion arose due to the lack of comparative material and technical difficulties in studying teeth in 2 mm jaws.

Specimens of *Kelloggella* are rare in collections. The species are known from few areas, only oceanic islands of the tropical western and central Pacific Ocean. Although the species are known from very shallow water, their small size has probably contributed to their apparent rarity. Little is known of the habits of the species, although these are under study by Helen Larson at Guam. While separable on fin ray counts, the species can be most easily separated by colouration.

METHODS

The following abbreviations are used in reference to material examined: AMNH, American Museum of Natural History, New York; AMS, Australian Museum, Sydney; ANSP, Academy of Natural Sciences, Philadelphia; BC, University of British Columbia; BPBM, Bernice P. Bishop Museum, Honolulu; CAS, California Academy of Sciences, San Francisco; LACM, Los Angeles County Museum of Natural History; SU, Stanford University (specimens now in CAS); UG, University of Guam; USNM, National Natural History Museum, Washington, DC.

All fish lengths given are standard length. All measurements were taken with the aid of an ocular micrometer.

The first ray of the anal and second dorsal is always a spine (= simple ray) in the species studied. The remaining rays are all segmented. The last ray of the dorsal and anal fins consists of two elements, in contact, though distinct through the extreme base. Ray counts in Table 1 are total ray counts. Vertebrae were counted from radiographs and counts include the urostyle. The osteology was studied from trypsin-prepared cleared-and-stained specimens.

Kelloggella Jordan and Seale

Kelloggella Jordan and Seale 1905 (in Jordan and Evermann): 488. (Type species *Enypnias oligolepis* Jenkins, by monotypy.)

Kelloggella Jordan and Seale, 1906: 409. (Type species *Kelloggella cardinalis* Jordan and Seale, by original designation.)

Itbaya Herre, 1927: 288. (Type species, *Itbaya nuda* Herre, by original designation.)

Atuona Herre, 1935: 428–429. (Type species, *Atuona tricuspidata* Herre, by original designation.)

Agunia Fowler, 1946: 207. (Type species, *Agunia quindecimfasciata* Fowler, by original designation.)

All species of *Kelloggella* examined share the following characters: Teeth of jaws tricuspid, outer row enlarged. Body elongate and compressed (depth into standard length 5 to 7). Head strongly compressed, interorbital region elevated above laterally placed eyes. Branchiostegal rays 5. Scales absent. Head pores absent. First dorsal fin with 6 spines. Second dorsal rays 11 to 13. Anal rays 8 or 9. Gut elongate. First dorsal fin low, spines equal to or slightly longer than rays of second dorsal. Snout evenly rounded in lateral view. Anal spine under third or fourth ray of second dorsal. Vertebrae 11 + 15 = 26. Only one inter-

hemal before first hemal spine. Pectoral rays few, 12 to 15, all but two branched. Gill opening narrow (lower attachment of membrane just below pectoral base). Mouth slightly oblique, ending approximately under middle of eye, anterior margin of jaws directly under anterior tip of snout. Pelvic disc short, reaching about one-third to one-half of distance to anus; pelvice I, 5, fused into a cup-shaped disc. Papillae of lateralis system poorly developed; a few widely spaced papillae around dorsal, posterior, and ventral margin of eye; one line of widely spaced papillae from posterior margin of eye to just above upper and posterior margin of operculum. Each nostril with a raised rim, that of anterior nostril longer, sometimes tubular.

The osteology of three cleared specimens of *K. oligolepis* from Easter Island was studied. This species shows considerable reduction in the extent of ossification of several bones. The supraoccipital crest and the lower fork of the posttemporal are absent. The pectoral radials are poorly ossified. The frontal is incomplete. There is a gap between the frontal and the surrounding bones. Gosline (1955) also discussed the osteology of this species.

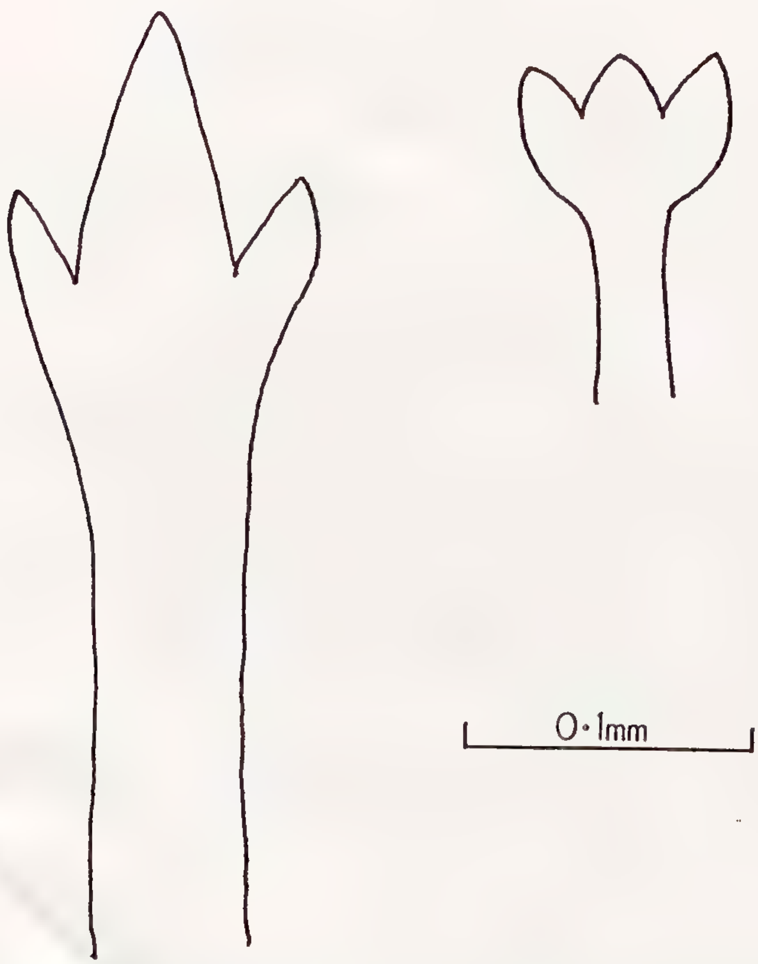


Figure 1.—Enlarged tricuspid tooth in the outer row of the upper jaw of *Kelloggella* (left) and tooth from an inner row. Scale 0.1 mm.

The mouth shape, elongate compressed body, lack of scales, elongate gut, short pelvic fins, and dentition separate this genus from other gobiids. The relationship of the genus to other gobiids is unknown. In all species of the genus examined the teeth of the outer row in each jaw are enlarged, and the median cusp of each tooth is the longest (Fig. 1). In all species, one or both lateral cusps may be lacking on some teeth in the outer row of the upper jaw in a given individual. Large males have one to four pairs of enlarged curved conical teeth, laterally in the inner row of the lower jaw. The anterior teeth in this row are smaller, simple (in both sexes), and conical. In each jaw there are three to seven rows of smaller tricuspid teeth, with equal-sized cusps. Posteriorly these rows converge into one or two rows.

Since the species differ in few characters only diagnostic characters are given in the species descriptions.

The species of *Kelloggella* are separable on colouration, dentition, and fin ray counts. There is some overlap between species in fin ray counts. Based on specimens studied the following percentage of misidentications can result from the counts: second dorsal rays 11 per cent; anal rays 5 per cent; pectoral rays 9 per cent; and segmented caudal rays 7 per cent.

Key to the species of **Kelloggella**

1. Body without transverse bands or distinctive marks.
   (Four or five inner rows of small tricuspid teeth in jaws. Second dorsal I, 12. Anal, I, 8. Pectoral rays modally 14. Segmented caudal rays modally 16). Samoa, Tonga, and Guam .... *K. cardinalis* (Jordan & Seale)

1. Body with transverse bands or a series of transverse blotches, appearing as interrupted bands 2

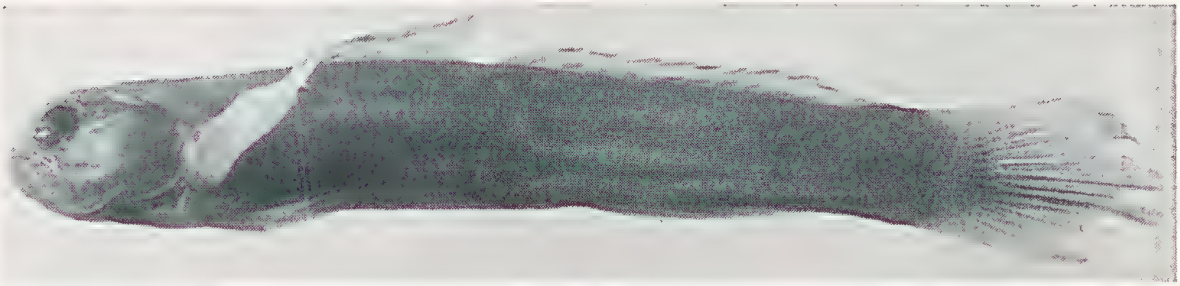
2. Body with seven dark bands from the origin of the first dorsal fin to the base of the caudal; interspaces broad in adults, about equal to band width or broader. Caudal fin with dark bands dorslly. Six or seven inner rows of small tricuspid teeth in each jaw. Second dorsal modally I, 12. Anal modally I, 8. Pectoral modally 14. (Segmented caudal rays 16). Marquesas ....
   K. tricuspidata (Herre)

2. Body with eight to 13 dark bands, which may be interrupted by a series of spots along the midside; interspaces equal to or much narrower than dark bands. Caudal fin dusky or clear, without distinct bands or spots. Three or four inner rows of small tricuspid teeth in each jaw. Second dorsal usually I, 10-11. Anal modally I, 7. Pectoral usually 12 or 13 3

3. Body with eight to 11 dark bands; interspaces between band narrow in adults, about one-fifth band width. Segmented caudal rays typically 15. Second dorsal usually I, 10-11. Pectoral modally 13. Ryu Kyu Islands, Hawaii, and Easter Island .... *K. oligolepis* (Jenkins)

3. Body with about 11 to 13 spots along midline in females above and below this line a series of spots along bases of median fins or with 11 to 13 dark bands in males. Segmented caudal rays modally 16. Second dorsal modally I, 10. Pectoral modally 12. Raratonga and Eniwetok ....
   .... *K. centralis*, new species.

Kelloggella cardinalis (Jordan and Seale)



First Plate.—*Kelloggella cardinalis*, Tonga, BPBM 14662. 25 mm SL. Photo by Charles Turner.

Kelloggella cardinalis Jordan and Seale, 1906: 409, pl. 53, fig. 1 (type locality Samoa). Schultz, 1943 (listed after Jordan and Seale).

Itbaya nuda Herre, 1927: 288–289, pl. 23, fig. 2 (type locality Itbayat, Philippines). Herre, 1935: 429 (comparison with *Atuona tricuspidata*). Fowler, 1946: 207 (comparison with *Agunia quindecimfasciata*).

Fin ray counts are given in Tables 1 and 2. Inner row of teeth in lower jaw with two to four pairs of enlarged conical teeth, larger in males. Adults with slight fleshy crest extending from behind eyes to before eyes.

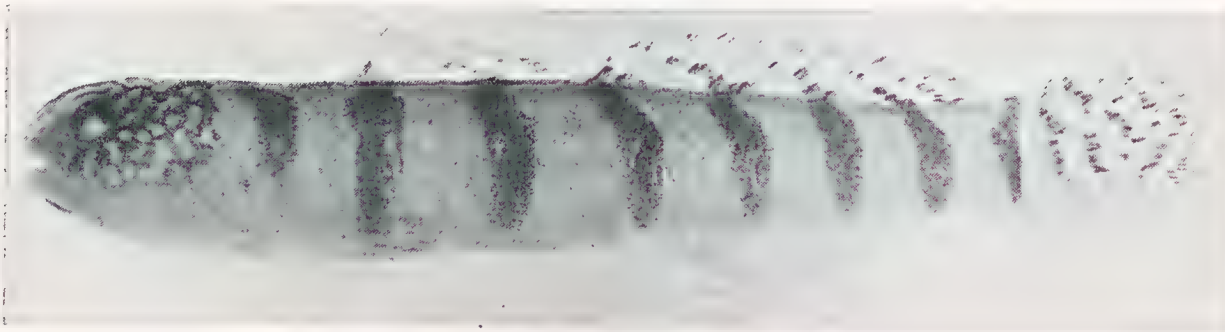
Coloration in alcohol—Body uniformly brown or black, covered with evenly spaced minute dark spots. A few small spots below eye, sometimes forming two irregular vertical bands. Bases of dorsal fins dusky, central part lighter; a faint black longitudinal stripe near distal margin of fins. Anal, caudal, pectoral, and pelvic fins clear to dusky, without spots or bands.

Colouration of fresh material—Body grass-green to greenish-black. Dorsal and anal fins bright cherry-red to bright orange edged with black. Caudal fin bright cherry-red to grey. Pectoral and pelvic fins green to golden-green (after Jordan and Seale, 1906).

Herre (1927) characterized *Itbaya nuda* as lacking canines in the lower jaw, having simple teeth in the outer row of the upper jaw, having a prominent fleshy interorbital crest, and in having a uniformly colored body. He did not indicate whether the inner rows of teeth were tricuspid. The interorbital crest was found to result from dehydration of the prominent compressed, fleshy, interorbital and snout regions in large specimens. The outer row of teeth in the upper jaw has small lateral cusps, with the outer cusp often absent. The specimens from Guam do differ from those from more eastern areas in usually having shorter canines, but some specimens from Guam have prominent curved teeth. The specimens from Guam also have fewer spots under the eye. These differences are minor, and it is very likely that Herre incorrectly reported simple teeth in the upper jaw. It is apparent that *Itbaya nuda* is a species of *Kelloggella* and is regarded here as a synonym of *K. cardinalis.* Herre reported four branchiostegal rays in *Itbaya* rather than five as always found in gobiids.

Samoa: Holotype and paratype, 2 (23–25) USNM 51785. One paratype, SU 8699. New Hebrides: ANSP 71395 1 (23); ANSP 91354 9 (9–21). Tonga: BPBM 14662 4 (21–25). Guam: USNM 124063 1 (22); UG (uncatalogued, 15 May 1972, H. Larson) 5 (14–21).

Kelloggella tricuspidata (Herre)



Second Plate.—*Kelloggella tricuspidata,* Marquesas Islands, BPBM 10872. 26 mm SL. Photo by Gregory Millen.

Atuona tricuspidata Herre, 1935: 429–430 (type locality Atuona, Hiva Oa Island, Marquesas Islands). Herre, 1936: 383–384, fig. 32 (redescription).

Fin ray counts are given in Tables 1 and 2. Inner row of teeth in lower jaw with two to four pairs of enlarged conical teeth, more prominent in males. Males without distinct fleshy interorbital crest, but with interorbital region elevated above eyes.

Coloration in alcohol—Body light brown or tan, with eight dark brown transverse bands (seven bands from first dorsal origin to caudal peduncle). Head light below and darker above; darker area of head with several small white spots. Caudal fin with four or five dark brown transverse bands covering upper two-thirds of fin. Dorsal fins with dark oblique bands extending upward and forward from dark body bands in young; fins becoming darker in large specimens with numerous white spots. Pectoral, pelvic and anal fins clear in females, dusky in males.

Coloration of fresh material—Body deep dull green with eight broad blackish-brown bands. Interspaces greenish, but abruptly white dorsally. Top and sides of head black, spotted with green. First dorsal black with two or three transverse rows of pale green spots, or most of first dorsal red, and upper margin of second dorsal broadly red. Anal and ventrals dusky or black, pectorals clear. (After Herre, 1935 and field notes of J. Randall.)

The holotype is in the Field Museum of Natural History, Chicago.

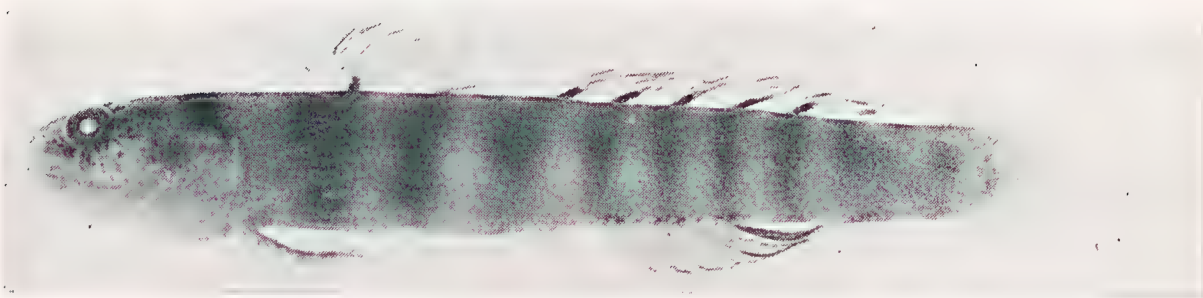
This species is known only from tidepools of the Marquesas Islands.

Herre (1935) reported the following counts for the holotype: D. VI, I, 11. A. I., 8.

MATERIAL EXAMINED

Marquesas Islands, Hiva Oa Island: seven paratypes, SU 24424; 1 (15), USNM 177359 USNH 117325 1(15). Nuku Hiva, Marquesas Islands: BPBM 10872 17 (10–26). Marquesas Islands: ANSP 83048, five specimens.

Kelloggella oligolepis (Jenkins)



Third Plate.—*Kelloggella oligolepis,* Easter Island, BPBM 6742, 22 mm SL. Photo by Gregory Millen.

Enypnias oligolepis Jenkins, 1903: 504–505, fig. 45 (type locality Honolulu, Hawaii).

Enypnias desquamatus Brigham, 1904:21 (type locality Honolulu, Hawaii, name only, a nomen nudum).

Kelloggella oligolepis.—Jordan and Seale, 1906: 409 (placement in *Kelloggella*). Kendall, and Radcliffe, 1912: 147 (Easter Island). Fowler, 1928: 408 (description and synonomy). de Buen 1963: 62 (Easter Island).

Agunia quindecimfasciata Fowler 1946: 207–208, fig. 68 (type locality, Ryu Kyu Islands).

Fin ray counts are given in Tables 1 and 2. Inner row of teeth in lower jaw with two to four pairs of enlarged conical teeth, more prominent in males. Males without a fleshy interorbital crest or prominently elevated interorbital region.

Coloration in alcohol—Body brown or light tan, with nine to 11 dark brown or black transverse bands. In adults, bands as broad or much broader than light interspaces. Dark brown or black spot on side of head above operculum. Series of dark brown or black spots, sometimes forming bands radiating downward from posterior and lower margin of eye. Base of first dorsal dusky. Black spot at base of first dorsal between fifth and sixth dorsal spines, and similar and fainter spot at base between third and fourth spines. Second dorsal light with bands formed by extension of body bands, paralleling fin rays. Caudal, pectoral, pelvic, and anal fins dusky to blackish being darker in males.

Coloration of fresh material from Easter Island—Similar to preserved coloration. Head light brown. Body bands dark brown to black. Interspaces between dark bands white on body and fins. First dorsal fin white interrupted by dusky semicircular bands connecting two dark spots at base of fin. (Based on colour photo by J. Randall.)

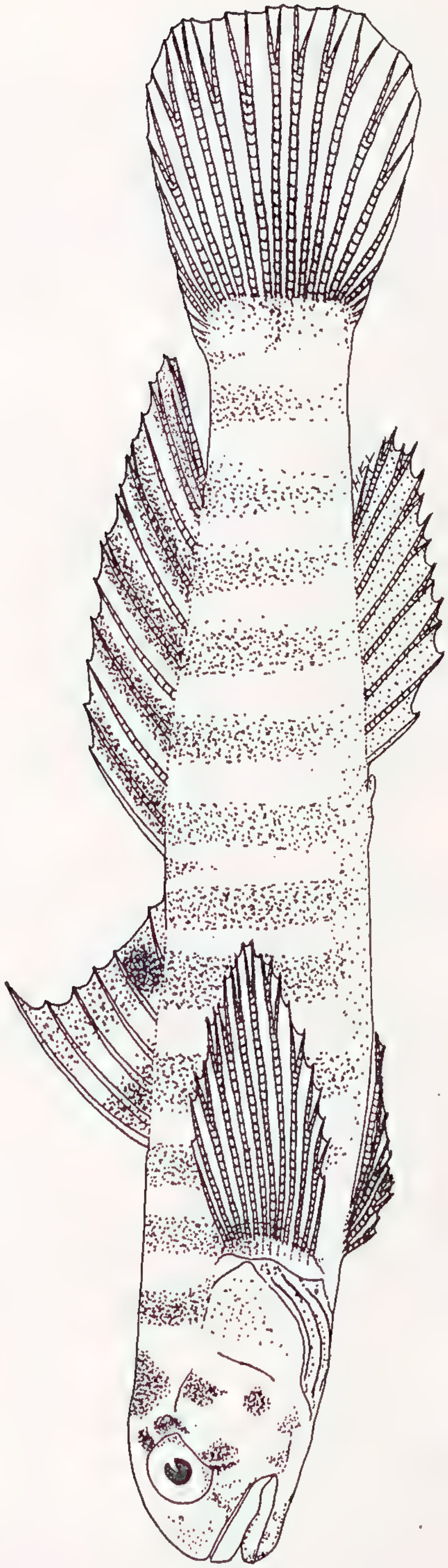
Jenkins (1903) reported that this species is scaled on the caudal peduncle, but I am unable to find scales or scale pockets in any of the material examined. Also, the figure given by Jenkins shows faint bands on the caudal fin, which I do not find (but most of the Hawaiian material is faded).

I am unable to find differences between Hawaiian and Easter Island material, except that the bands are on the average slightly narrower in Easter Island material. In young individuals (less than 16 mm in standard length) from Easter Island the interspaces are about as wide as the dark bands. In larger specimens the bands become narrower in relation to the interspaces. In 20 mm specimens the interspaces are about one-third as wide as the bands. In Hawaiian material the interspaces become very narrow in specimens 16 mm and larger. Since the interspace width changes with growth it is unlikely that the minor differences between the Hawaiian and Easter Island material are significant.

The holotype of *Agunia quindecimfasciata,* 18 mm in standard length, agrees in colour pattern and in dentition with Easter Island and Hawaiian material of *K. oligolepis.* The dorsal and pectoral ray counts are low for *K. oligolepis,* but within the range of that species. Consequently, *Agunia quindecimfasciata* is regarded here as a synonym of *K. oligolepis.*

MATERIAL EXAMINED

Ryu Kyu Islands: holotype of *Agunia quindecimfasciata,* ANSP 71079 1 (18). Hawaiian Islands: BPBM 5497 10 (13–24); BPBM 5498 17 (12–19); SU 7844, six specimens; USNM 126574 2 (13–16); holotype of *E. oligolepis,* USNM 50715, 1 (16). Easter Island: AMNH 12990 1 (19); BPBM 6741 2 (18–21); BPBM 6742 2 (20–22); BC 65–422 31 (14–20); USNM 65549 5 (20–26).



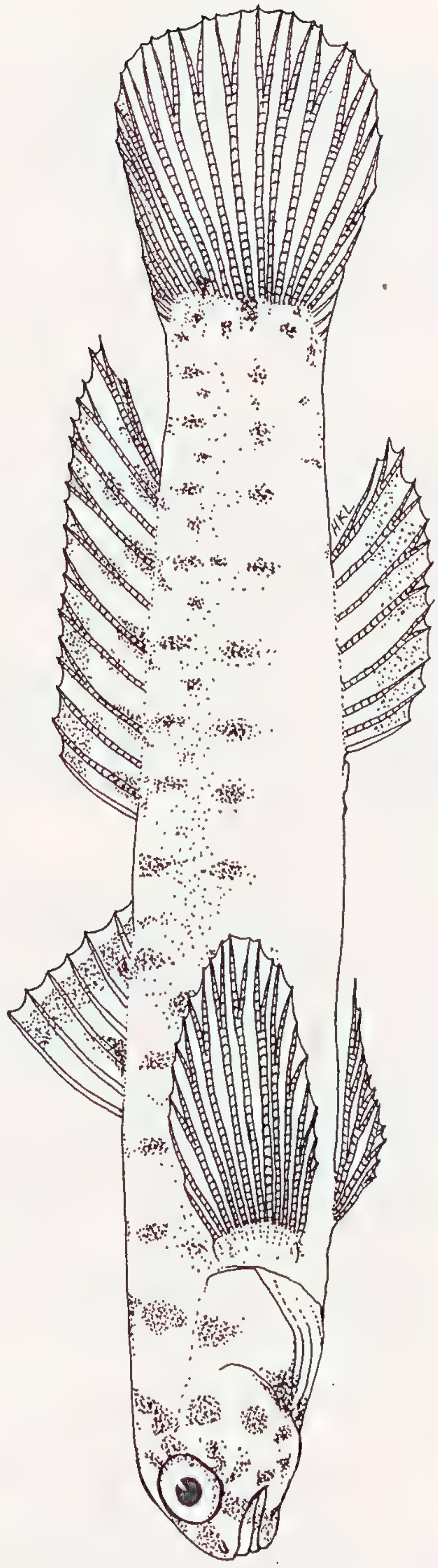


Figure 2.—Holotype of *Kelloggella centralis, Raratonga* BPBM 14660, male, 20.4 mm SL 1, left. Drawing by Helen K. Larson.

Figure 3.—Female paratype of *Kelloggella centralis,* BPBM 14661, 20 mm SL 1, left. Drawing by Helen K. Larson.

Kelloggella centralis new species

Fin ray counts are given in Tables 1 and 2. Measurements of holotype in millimetres: standard length 20.4, head length 4.9, head width 2.9, head depth 3.1, body depth at anal origin 3.0, least caudal peduncle depth 2.5, caudal peduncle length 4.8, eye 1.1, upper jaw 1.7, snout 1.3, pectoral length 4.5, pelvic length 3.2, caudal length 4.4, base of second dorsal 3.8, base of anal 3.4. Inner row of teeth in lower jaw with two to four pairs of enlarged curved teeth, more prominent in males. Outer row of teeth in jaws enlarged and tricuspid. Three or four inner rows of small tricuspid teeth in each jaw. Males without a distinct fleshy interorbital crest, or elevated interorbital region.

Coloration in alcohol—Male. Body light brown with 11 to 13 dark brown transverse bands, these narrower than interspaces; bands not reaching ventral profile; posterior bands faint and often indistinct. Top of head with transverse brown bands, broken up into spots on sides of head. Body bands extending upward onto dorsal fins as oblique bars. Prominent black spot on membrane of first dorsal fin between fifth and sixth dorsal spines. Anal fin clear basally and with dusky longitudal band near tip. Pectoral, pelvic and caudal fins clear to faintly dusky. Female. Body light brown with two rows of dark spots; upper row directly below dorsal fins, and lower row along midside; spots in lower row directly under and paired with upper spots. Below spots on midside a row of subcutaneous spots along base of anal fin. Head with dark brown spots. Base of dorsal fins with vertical brown bars; dorsal fins with irregular dusky margins. No prominent spot on first dorsal fin between fifth and sixth spines. Caudal fin sometimes with rows of faint spots. Anal with a dusky bar near tip. Pectoral and pelvic fins clear.

Kelloggella centralis is most closely related to *K. oligolepis,* being similar in dentition, head shape, and anal ray counts. It differs from *K. oligolepis* in pectoral, dorsal, and segmented caudal ray counts (Tables 1 and 2), and in the marked sexual dichromatism.

Name—*centralis,* L. central, referring to the central distribution in the Pacific Ocean in relation to its nearest relative.

MATERIAL EXAMINED

Holotype, BPBM 14660, a male 20.4 mm SL. Nikau, Rarotonga. Coll. J. Powell and R. H. Snider, 15 January, 1965.

Paratypes: AMS I. 17021–001 4 (16–20), taken with holotype; BPBM 14661 19 (11–22), taken with holotype. Eniwetok: LACM 6671–21, two specimens. USNM 213478 2 (15–17), taken with holotype. CAS 31018 2 (17–18), taken with holotype.

RELATIONSHIPS OF SPECIES OF *KELLOGGELLA*

In dentition, general head shape and fin ray counts of the four species fall into two groups. *K. cardinalis* and *K. tricuspidata* have four to seven inner rows of tricuspid teeth in the upper jaw, elevation of the interorbital region and higher dorsal, anal and pectoral ray counts. *K. oligolepis* and *K. centralis* have three to four inner rows of tricuspid teeth in the upper jaw, no elevation of the interorbital region and lower fin ray counts.

DISTRIBUTION OF SPECIES OF *KELLOGGELLA*

Few collections of *Kelloggella* have been made and currently all species are known only from insular areas of the Pacific Ocean. *K. cardinalis* is apparently widely distributed, known from Guam, the Philippine Islands, the New Hebrides, Tonga and Samoa. Its nearest relative *K. tricuspidata* is known only from the Marquesas Islands to the east. *K. oligolepis* is known from peripheral areas; Ryu Kyu Islands, the Hawaiian Islands in the north Pacific and Easter Island in the southeastern Pacific. Its nearest relative, *K. centralis,* is known from the central Pacific areas of the Cook Islands and Eniwetok Atoll in the Marshall Islands.

ACKNOWLEDGMENTS

I would like to thank Drs John E. Randall, I. Efford, R. J. Lavenborg, E. Lachner, and W. Eschmeyer for supplying material for this study. Dr Randall supplied a colour photo of the Easter Island *Kelloggella oligolepis*. I would also like to thank Dr J. R. Paxton for reviewing this manuscript, Mrs H. K. Larson kindly drew figures 2 and 3.

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Table 1

Dorsal and anal counts for various populations of species of *Kelloggella*

An asterisk indicates holotype

Species	D1 Simple Rays		Second Dorsal Rays				Annal Rays				
	6	7	10	11	12	13	6	7	8	9	10
K. cardinalis											
Samoa	1	..	..	..	1	2*	..	..	..	3*	..
Tonga	3	..	..	..	1	3	..	..	1	3	..
New Hebrides ..	5	..	..	..	1	9	..	..	1	9	..
Guam	5	..	..	..	..	6	..	..	1	5	..
Totals	13	..	..	..	3	20	..	..	3	20	..
K. tricuspidata	10	..	..	..	..	26	..	..	1	24	1
K. oligolepis											
Hawaii	8*	...	..	5	25*	..	1	1	27*	1	..
[1]Ryu Kyu Islands ..	1*	..	..	1*	..	..	..	..	1*	..	..
Easter Island	4	..	..	2	20	2	..	..	24	..	..
Totals	13	..	..	8	45	2	1	1	52	1	..
K. centralis	28*	1	1	27*	2	..	..	..	27*	2	..

[1]Holotype of *Agunia quindecimfasciata*

Table 2

Segmented caudal and pectoral ray counts for various populations of species of *Kelloggella*

An asterisk indicates holotype

Species	Segmented caudal rays				Pectoral rays			
	13	14	15	16	12	13	14	15
K. cardinalis—								
Samoa	..	..	..	..	..	..	..	..
Tonga	..	..	..	4	..	.	3	1
New Hebrides	..	..	..	..	..	1	7	1
Guam	..	..	1	5	..	1	5	..
Totals	..	..	1	9	..	2	16	2
K. tricuspidata	..	..	1	15	..	1	20	4
K. oligolepis—								
Hawaii	1	1	24	..	1	26	3	..
[1]Ryu Kyu Islands ..	..	..	1*	..	1*		..	..
Easter Island	..	..	4	1	1	17	6	..
Totals	1	1	28	2	3	43	9	..
K. centralis	..	..	2	26*	25*	4	..	..

Holytype of *Aguna quindecimfasciata*

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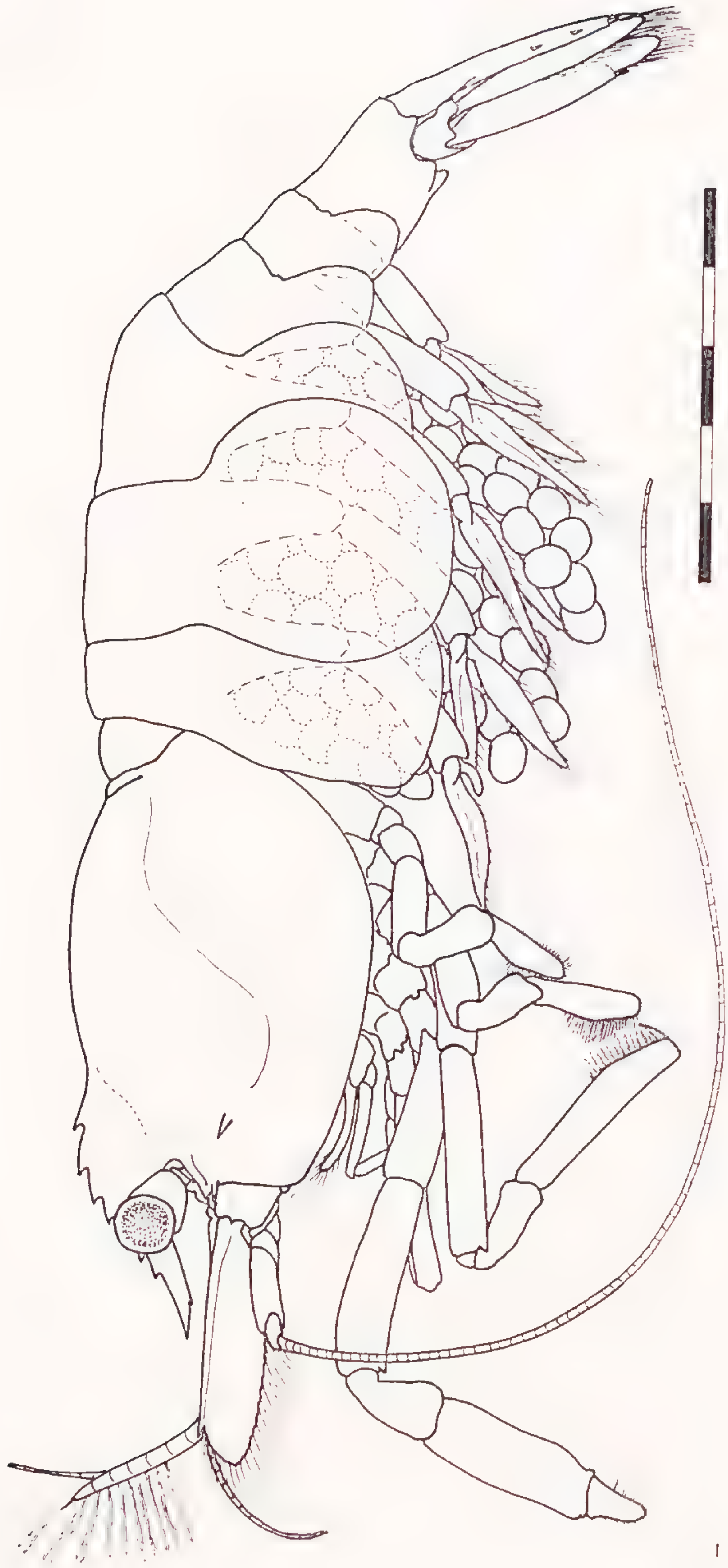

Fig. 1.—*Periclimenes colemani* sp. nov. Ovigerous female allotype.

Periclimenes colemani sp. nov., a new shrimp associate of a rare sea urchin from Heron Island, Queensland (Decapoda Natantia, Pontoniinae)

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Figures 1–8.

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SUMMARY

Periclimenes colemani, a new species of pontoniinid shrimp, is described and illustrated. This species was found at Heron Island on the Australian Great Barrier Reef. It lives in pairs on the test of the sea urchin *Asthenosoma intermedium* H. L. Clark. The new species is considered to occupy a rather isolated systematic position, most closely related to another echinoid associate, *P. hirsutus* Bruce. It is also remarkable for its cryptic white, red spotted colour pattern. The associations between Indo-West Pacific *Periclimenes* spp. and echinoids are briefly reviewed.

INTRODUCTION

The association of echinoderms with many species of the large pontoniinid genus *Periclimenes* Costa, has been well established for many years but relatively few species have been found to occur in associations with echinoids. The first species to be reported as an echinoid associate was *Periclimenes maldivensis* Bruce, by Borradaile, (1915, as *P.* (*Cristiger*)*brocki*). Subsequently, Balss (1913, 1914) described *P. hertwigi,* which was also later recorded by Kubo (1940, as *P. gracilirostris*), a deep water species, that was found between the spines of an echinothuroid urchin. More recently several species have been reported from shallow water mainly in association with diadematid urchins, but also with a temnopleurid echinoid (Bruce, in press).

From Australian waters, only two species have so far been recorded. *Periclimenes hertwigi* Balss has been found on the echinothuroid *Areosoma thetidis* (H. L. Clark) in deep water off Mooloolaba, Queensland (Bruce, 1972), and *Periclimenes zanzibaricus* Bruce, has also been found on the diadematid urchin *Centrostephanus tenuispinus* (Clark) from Geraldtown, Western Australia (Bruce, 1973). The discovery of a further species of echinoid associate is also of particular interest as the association is with a "venomous" urchin of the family Echinothuriidae.

I am most grateful to the collector, Neville Coleman, for the opportunity to examine this and the other interesting shrimps from his collections and for the additional information and photographs made available.

SYSTEMATICS

Periclimenes colemani sp. nov.

Material examined.—1 ♂ (holotype), 1 ovigerous ♀ (allotype), Wistari Reef, Heron Island, Capricorn Group, Queensland, Australia. 12 m. Coll. 18th July, 1973, N. Coleman, ref. No. 305.

Description.—Medium sized, robustly built pontoniine shrimps. The female is distinctly larger and more swollen in appearance than the male, with smaller second pereiopods.

The carapace is smooth and moderately humped dorsally in the female. The rostrum is well developed and extends anteriorly to the level of the proximal end of the terminal segment of the antennular peduncle in both sexes. In the male the rostrum is almost horizontal and in the female, distinctly depressed. The lateral carina is broadened and continuous with the orbital margin posteriorly, but is feebly developed over the distal half of the rostrum. The dorsal lamina is strongly elevated posteriorly, with a convex upper border bearing seven acute teeth in the female and eight in the male and extending posteriorly well behind the posterior orbital margin. The most posterior tooth is situated behind the level of the posterior margin of the orbit. The dorsal teeth are generally similar but become slightly smaller and more closely spaced distally. The tip of the rostrum is slender and acute and devoid of teeth. The ventral border is almost straight in the male and moderately concave in the female. In both, a single small tooth is present distally. In the male, the ventral tooth is situated slightly posteriorly to the eighth dorsal tooth, and in the female, distinctly in advance of the seventh dorsal tooth. Supraorbital and epigastric spines are lacking. The orbit is feebly developed and the inferior orbital angle is slightly produced, and acute in lateral view. The antennal spine is distinct, slender and submarginal, situated immediately ventrally to the inferior orbital angle and directed horizontally. The hepatic spine is large and robust, situated at a lower level than the antennal spine and directed upwards. The antero-lateral angle of the branchiostegite is bluntly angled in the female and broadly rounded in the male.

The abdominal segments are smooth. The third abdominal segment is slightly posteriorly produced in the dorsal midline in the female but not in the male. The fifth abdominal segment is 0.7 times the length of the sixth segment which is 0.9 as deep as long in both sexes. The pleura of the first five abdominal segments are broadly rounded, with the first three expanded in the female, and the last two are feebly produced posteriorly. The posterior ventral angle of the sixth abdominal segment is subacute and the posterior lateral angle is also produced to a small acute point.

The telson is about 2.1 times the length of the sixth abdominal segment, and is 2.8 times longer than broad anteriorly. The lateral margins are feebly convergent over the anterior half and more strongly over the posterior half. The posterior margin is about one third of the anterior width and is feebly produced centrally. Two pairs of small dorsal spines are present, the anterior slightly larger than the posterior, both situated close to the lateral margins. The anterior

pair is at 0.6 of the telson length and the posterior pair at 0.8. The posterior margin bears a pair of small lateral spines, similar to the dorsal spines. The intermediate spines are large and stout, about 2.5 times longer than the lateral spines. The submedian spines are also well developed, about 0.7 of the length of the intermediate spines and devoid of setules.

The eyes present no special features. The cornea is large and hemispherical with a distinct accessory pigment spot. The podophthalmite is about 1.2 times longer than the distal width which is subequal to the corneal diameter, and is slightly expanded proximally.

The antennules are normal and the peduncle exceeds the tip of the rostrum by the distal segment in male and female. The proximal peduncular segment is twice as long as broad. The medial border is straight with a strong tooth ventrally. The lateral border is moderately convex. The stylocerite is well developed, acute distally and reaches to the level of the middle of the medial border. The antero-lateral margin is broadly produced and bears a stout disto-lateral tooth that reaches to the level of the proximal margin of the distal peduncular segment. The statocyst is normally developed and contains numerous discrete granules. The intermediate segment of the peduncle is obliquely articulated with the distal segment. The dorsal length is about 0.6 of the width. The lateral margin is laminar and setose and a smaller lamina is present on the medial side also. The distal segment is almost twice as long as wide, twice the dorsal length of the intermediate segment and the two segments together are equal to 0.4 of the median length of the proximal segment. The lower flagellum is slender and a little longer than the peduncle. The upper flagellum is biramous, with the first six segments of the rami fused. The shorter ramus consists of only two free segments and the longer of about fifteen. Ten groups of aesthetases are present.

The antenna has a robust basicerite with an acute lateral tooth. The merocerite and ischiocerite are normal. The carpocerite is subcylindrical, slightly compressed, 2.2 times longer than broad and reaches nearly to the middle of the length of the scaphocerite. The scaphocerite is broad, about 2.5 times longer than wide, with the greatest width at about half the length. The lateral border is very feebly convex with a strong disto-lateral tooth. The lamina is broad distally and distinctly exceeds the tip of the disto-lateral tooth. The scaphocerite extends well beyond the end of the antennular peduncle. The flagellum is well developed, slender, extending posteriorly to the posterior margin of the third abdominal segment.

The epistome is normal and without horns. The labrum shows no special features. The sternite of the second thoracic segment shows a small median knob on a transverse ridge. The third sternite is unarmed. The fourth sternite is without a median process between the coxae of the pereiopods but a distinct transverse ridge is present posteriorly, with a small median notch. A similar but rather larger ridge is also present on the fifth sternite posterior to the coxae of the second pereiopods. The following sternite are unarmed.

The mouthparts are typical of the genus. The mandible is without a palp. The corpus is robust, with a small incisor process bearing three acute distal teeth. The molar process is stout, obliquely truncated distally. The ventral aspect bears a dense fringe of stout setae. The dorsal aspect bears two stout teeth, the anterior tooth with a tuft of stout setae and the posterior tooth with a group of fine short setae.

The maxillula has a distinctly bilobed palp. The upper lobe is small and rounded. The lower lobe is larger with a short hooked seta arising from a small ventral process. The anterior aspect bears a short simple seta. The upper lacinia is moderately narrow with numerous setae distally and six simple terminal spines. The lower lacinia is slender, with numerous long slender spiniform setae distally.

The maxilla has a moderately stout palp, bearing only a short simple seta near the middle of its median margin. The basal region bears an elongated slender bilobed endite. The terminal lobes are subequal, each bearing about ten short simple setae. The coxal portion is slightly produced medially but is without an endite. The scaphognathite is well developed, about 2.6 times longer than broad, with the antero-medial margin scarcely emarginated.

The first maxilliped has a subcylindrical palp, with a single short slender terminal seta and a longer stouter plumose preterminal seta. The basal endite is large and broad, with a straight medial and broadly rounded antero-lateral margin. The distal and medial borders are provided with numerous slender simple setae. The small rounded coxal endite is separated by a distinct notch. It is sparsely setose, but some long stout simple setae are present distally. The caridean lobe of the exopod is well developed but relatively narrow and slightly exceeds the tip of the palp. The flagellum of the exopod is normally developed with six plumose terminal setae. A large deeply bilobed epipod is also present.

The second maxilliped is of normal form. The dactylar segment is moderately broad, about 3.5 times longer than wide, with numerous finely dentate spines along the medial margin. The disto-medial border of the propodal segment is broadly rounded with long slender simple spines. The carpus, merus and ischiobasis are typical. The coxa bears a small medial protuberance, with a subrectangular epipod laterally, without a podobranch. The exopod is well developed, with six plumose setae distally.

The third maxilliped is slender, extending anteriorly to the proximal end of the carpocerite. The ischio-merus and basis are completely fused, with a small notch indicating the point of junction on the medial border. The combined segment is about six times longer than the central width. The ischiomeral part tapers slightly distally and is sparsely provided with slender simple setae along the medial border. The basal portion is slightly expanded medially and also feebly setose. On the proximal medial dorsal part of the ischiomerus is a submarginal row of about ten short feeble plumose setae. The penultimate segment is about four times longer than wide, scarcely tapering and equal to about half the length of the antepenultimate segment. The medial border is provided with about eight pairs of slender setae. The terminal segment is about 0.6 of the length of the penultimate segment and tapers strongly distally. The medial aspect bears 5–6 small groups of shorter stouter finely serrulate spines. The exopod is well developed with a broad flagellum bearing eleven plumose terminal setae. The coxa is not produced medially but bears a large rounded epipod laterally. A small arthrobranch, with six branchial lamellae, is present laterally.

The first pereiopods are moderately slender and extend beyond the carpocerite by the chela and carpus. The palm of the chela is subcylindrical, slightly broadened and compressed distally, about twice as long as the maximum width. The fingers are about 0.8 of the length of the palm, distinctly spatulate, with a finely pectinate lateral cutting edge. The pectinations are very close set, regular with truncated tips distally. Numerous groups of setae are also present on the fingers and the proximal end of the palm bears several rows of short

cleaning setae. The chela is about 0.9 of the length of the carpus, which is slightly expanded distally, and about 4.5 times longer than wide. The merus is 1.1 times the length of the carpus, of uniform width and 5.0 times longer than wide. The ischium and merus are subequal in length, slightly less than one third of the length of the merus, with sparsely setose medial borders. The coxa is short and stout, with a large setose medial lobe.

The second pereiopods are slightly unequal and similar, larger in the male than in the female. The palm is subcylindrical, 3.9 times longer than wide in the male, in which it is slightly swollen proximally and 4.1 times longer in the female. The fingers are 3.7 times the palm length in the male and 3.4 in the female. The fingers are robust with distinctly hooked acute tips, and the length is a little more than three times longer than the breadth of the base. The distal two thirds of the cutting edges are entire. The dactylus bears a single small tooth at the end of the distal third of the cutting edge, larger and acute in the male, blunt in the female. On the fixed finger a small notch is situated opposite the dactylar tooth, with a single small tooth distally in the male and two smaller teeth in the female. Posteriorly an elevated row of three very small teeth is present. No fossa is present at the base of the dactylus. The carpus is short and stout, twice as long as wide distally, expanded distally and unarmed. The merus is robust, equal to 0.75 of the length of the palm in both sexes, about 3.5 times longer than wide. In the male the disto-ventral angle bears an acute tooth, but this is only feebly represented in the female. The ischium is about 0.75 of the meral length and tapers proximally. The basis and coxa are robust, without special features.

A number of the ambulatory pereiopods are lacking. The third pereiopod in the male exceeds the basicerite by the dactylus, propodus and carpus, and is relatively long and robust. The dactylus is small, with the carpus strongly compressed. The unguis is long, slender, slightly curved and very acutely pointed, subequal to the dorsal length of the corpus, and more than three times longer than the width at the base. The ventral border is carinate with the distal angle strongly produced and bearing a small acute accessory spine distally with a couple of rounded projections more proximally. Some sensory setae arise from pits adjacent to the base of the unguis. The propodus is seven times longer than the greatest width which occurs just distally to the midlength and slightly exceeds the length of the dactylus. The dorsal margin is straight but the proximal and distal parts of the ventral border are also straight but at a very obtuse angle to each other. The distal part of the ventral border bears two rather irregular longitudinal rows of spines, each with about 12–13 slender spines. A dense tuft of long simple setae arises on each side of these spines forming a dense brush and almost completely excluding the spines from view. The proximal half of the ventral border is without spines or setae. The carpus is 0.38 of the length of the propodus and is unarmed. The merus is 0.8 of the propodal length and 4.5 times longer than wide. There are no ventral spines present, but the disto-ventral angle bears an acute tooth. The ischium is unarmed and the basis and coxa present no special features.

The pleopods are normally developed. In the male the endopod of the first pleopod is about three times longer than the width, excluding the small lobe present on the distal part of the medial border. The distal border is rounded and sparsely setose. The central part of the lateral border bears five short plumose setae, and the proximal half of the medial border bears six short curved spines. On the male second pleopod, the appendix masculina slightly exceeds the appendix interna, and is about four times longer than wide distally. The distal end is slightly swollen and bears a row of about 12–13 slender spines

which extend down half the length of the lateral margin. Two short spines are also present disto-ventrally and a few more are present dorsally. The most medial spines are finely serrulate, but the rest are simple.

The uropods are without special features. The protopodite is rounded disto-laterally. The exopod is broad, about 2.5 times longer than wide, with an entire, slightly convex lateral margin ending in a small acute tooth with a large mobile spine medially. The endopod is about 2.8 times longer than wide and is slightly exceeded by the tip of the exopod, and both exceed the tips of the posterior telson spines.

Types.—The male specimen is designated as the holotype and the female, with mouthparts removed on the right side, as the allotype. Both specimens are deposited with the collections of the Australian Museum, registration numbers P. 20209 (Holotype), P. 20210 (Allotype).

Measurements.—(In millimetres)

	Holotype male	Allotype female
Total length, (approx.)	18.0	19.0
Carapace and rostrum	7.0	6.9
Post-orbital carapace length	4.3	4.8
Chela of second pereiopod	5.9	4.4
Diameter of ova	—	0.68

Colouration.—The colour pattern is almost identical in male and female and consists of a dense white ground colour with large deep red spots and bands, in general relatively larger in the male than in the female. The carapace and rostrum are white with a large red patch over the gastric region and a transversely oval patch over the cardiac region. An extensive red patch covers the antero-lateral region and is almost in contact with the gastric patch. A circular patch covers the central part of the branchiostegite. The abdomen is similarly white with a large median transversely oval patch dorsally on the second segment, a smaller circular patch on the third and an oval patch on the fifth. The dorsal lateral parts of the first segment are red and the posterior parts of the second, third and fourth pleura are largely red. The fifth abdominal segment is red dorsally and also on the pleuron and the posterior half of the sixth segment is also red. A broad band of red crosses covers the whole of the central region of the caudal fan. The basicerite and proximal part of the first segment of the antennular peduncle and the whole of the distal end of the scaphocerite are white, the rest of the antennae being red, with transparent flagella. The eyestalks are white, with pinkish corneae. The fingers of the first and second pereiopods are white, with the palm red except proximally. The carpus, merus and ischium are a similar red with a white zone distally. The ambulatory pereipods have the first and third fourths of the propodus red, with the merus similarly coloured. The carpus is white and the ischium is red with white distally.

Host.—*Asthenosoma intermedium* H. L. Clark (Echinothuriidae)

Habitat.—Coral reef at 12 m depth.

Remarks.—The collector observed pairs of shrimps on three separate host urchins. It was also observed that the shrimps are situated close together on the dorso-lateral aboral surface of the host in a small area of the shrimps, bare test devoid of spines, apparently caused by the presence of the shrimp.

Systematic Position of Periclimenes colemani sp, nov.

The new species *Periclimenes colemani* is most closely related to an other echinoid associate *P. hirsutus* Bruce, 1971. This species is found in association with the diadematid urchin *Astropyga radiata* (Leske). The most noteworthy similarity between the two species is shown by the setal brushes on the propods of the ambulatory pereiopods, similar features being lacking from all other species of the genus *Periclimenes.* The branchial formulae are similar and the morphology of the mouthparts show a very close resemblance although differing in some small details. The new shrimp does not show a close affinity to any other species of the genus *Periclimenes.*

Since the description of the original specimen of *Periclimenes hirsutus* Bruce, 1971, further specimens have become available for study. The original discussion overlooked the presence of spines along the ventral aspect of the ambulatory propods, which were completely obscured by the presence of the dense setal brush. Clearing with sodium hydroxide and staining with alizarin red S reveals that spines similar to those of *P. colemani* are also present in *P. hirsutus.* The spines are in two roughly longitudinal rows and are well developed posteriorly but decrease markedly in size distally along the propodus, so that the most distal spines are minute. Each spine is situated medially to the origin of one of the large groups of setae that arise along the ventro-lateral and ventro-medial aspects of the propodus. The differences between *P. colemani* and *P. hirsutus* are summarized in the following Table:

Periclimenes Colemani sp. nov.	*Periclimenes hirsutus* Bruce
1. Body glabrous.	Body generally hirsute.
2. Rostrum short and deep, distinctly shorter than the antennular peduncle.	Rostrum long and slender, distinctly exceeding the antennular peduncle.
3. Proximal part of dorsal lamina elevated to form a distinct crest.	No distinct rostral crest present.
4. Small ventral rostral tooth present.	No ventral rostral tooth present.
5. Hepatic spine large and robust, antennal spine slender.	Antennal spine robust, hepatic spine small and slender.
6. Scaphocerite broad, distally rounded.	Scaphocerite narrow, distally truncated.
7. First pereiopod with fingers strongly spatulate with pectinate cutting edges.	First pereiopod with fingers only moderately subspatulate, cutting edges entire.
8. Second to fifth pereiopods with well-developed disto-ventral meral tooth.	Second to fifth pereiopods with feeble disto-ventral teeth.
9. Propod of ambulatory pereiopods with well developed spines along whole length of the setal brush.	Propod of ambulatory pereiopods with feebly developed spines ventrally, mainly along proximal part of setal brush.
10. Setose brush of ambulatory propods extending over distal half only.	Setose brush of ambulatory propods extending over whole length of propod.
11. Setae of propodal brush simple.	Setae of propodal brush plumose.

12. Accessory tooth of dactyl very large and acute, much produced.	Accessory tooth of dactyl small and only feebly produced.
13. Dorsal telson spines situated on posterior third, not very small.	Dorsal telson spines very small all situated on posterior fourth.
14. Posterior telson spines normal.	Lateral spines minute, intermediate spines short and very stout with mobile tip.

Apart from a relatively close relationship to *P. hirsutus, P. colemani* does not appear to be closely related systematically to any of the other species of the genus, although several of its characteristic features are also found in some of these. The propodal brushes of the ambulatory pereiopods are to be found in a much less developed form in *P. curvirostris* Kubo. The disto-lateral meral teeth on the second to fifth pereiopods are also found in *P. lanipes* Kemp and *P. noverca* Kemp, both of which are also echinoderm associates. The host of *P. curvirostris* has not been identified, but is probably also an echinoderm. *P. maldivensis* Bruce is also an associate of an unidentified echinoid and has the meral teeth present, but it is without the propodal brushes.

DISCUSSION

The associations between caridean shrimps and echinoids have been recently summarized by Bruce (in press). Including *P. colemani,* seven species are now known to associate with echinoids, and some hosts of six species have been identified. Four species have only been found in association with a single host species, *P. colemani, P. hirsutus, P. insolitus* and *P. cristimanus. P. hertwigi* has been found on two species of host, both belonging to the same family, the Echinothuridae. *P. zanzibaricus* has been found in association with five host species, of four different genera, but all belonging to the same family, the Diadematidae. *P. maldivensis* a shallow water species, was reported to have been collected from urchins, but the identity of the hosts was not established (Borradaile, 1915; Bruce, 1969). The relationships are illustrated in the following table.

Associate	Host
1. *P. hertwigi* Balss	*Phormosoma* sp.
	Areosoma thetidis (H.L. Clark)
2. *P. hirsutus* Bruce	*Astropygia radiata* (Leske)
3. *P. cristimanus* Bruce	*Diadema setosum* (Leske)
	Diadema savignyi Michelin
4. *P. zanzibaricus* Bruce	*Echinothrix calamaris* (Pallas)
	Centrostephanus tenuispinis H. L. Clark
5. *P. insolitus* Bruce	*Pseudoboletiana indiana* Michelin
6. *P. colemani* sp. nov.	*Asthenosoma intermedium* H.L. Clark
7. *P. maldivensis* Bruce	Unidentified

One of the most striking characteristics of *P. colemani* is its unusual white and red colour pattern. Seen in isolation from its natural background, this colouration makes the shrimp extremely conspicuous. However, the pattern is cryptic and disruptive when on the host, so that the shrimps blend closely with their surrounding. The spines of the host are strongly ringed with red and white bands. None of the other species of *Periclimenes* found on echinoids have a similar colour pattern. They are in general uniformly coloured, matching the host, with a thin line of white along the side of the body.

The presence of only a single pair of shrimps on each of three separate hosts is unusual in echinoderm associated pontoniine shrimps, although normal in those found in molluscs.

In the case of other shrimp-echinoid associations, there have been no reports of any modifications or damage to the host. In the present association the activities of the shrimp appear to cause the development of a large area of test from which the spines have been lost. The shrimps are apparently permanently found on this bare area.

The *Periclimenes* species associated with echinoids appear also to fall into two natural groups—(i) occurring on the spines (*P. insolitus, P. cristimanus* and *P. zanzibaricus*) and (ii) occurring on the test (*P. colemani, P. hirsutus* and *P. hertwigi*). The position of *P. maldivensis* on the host is uncertain. *Asthenosoma intermedium* is said to be venomous, which may provide added protection for the shrimp and it may be noted here that in the course of examining numerous examples of the poisonous *Toxopneustes pileolus* from a wide variety of localities, no associated shrimps have so far been found.

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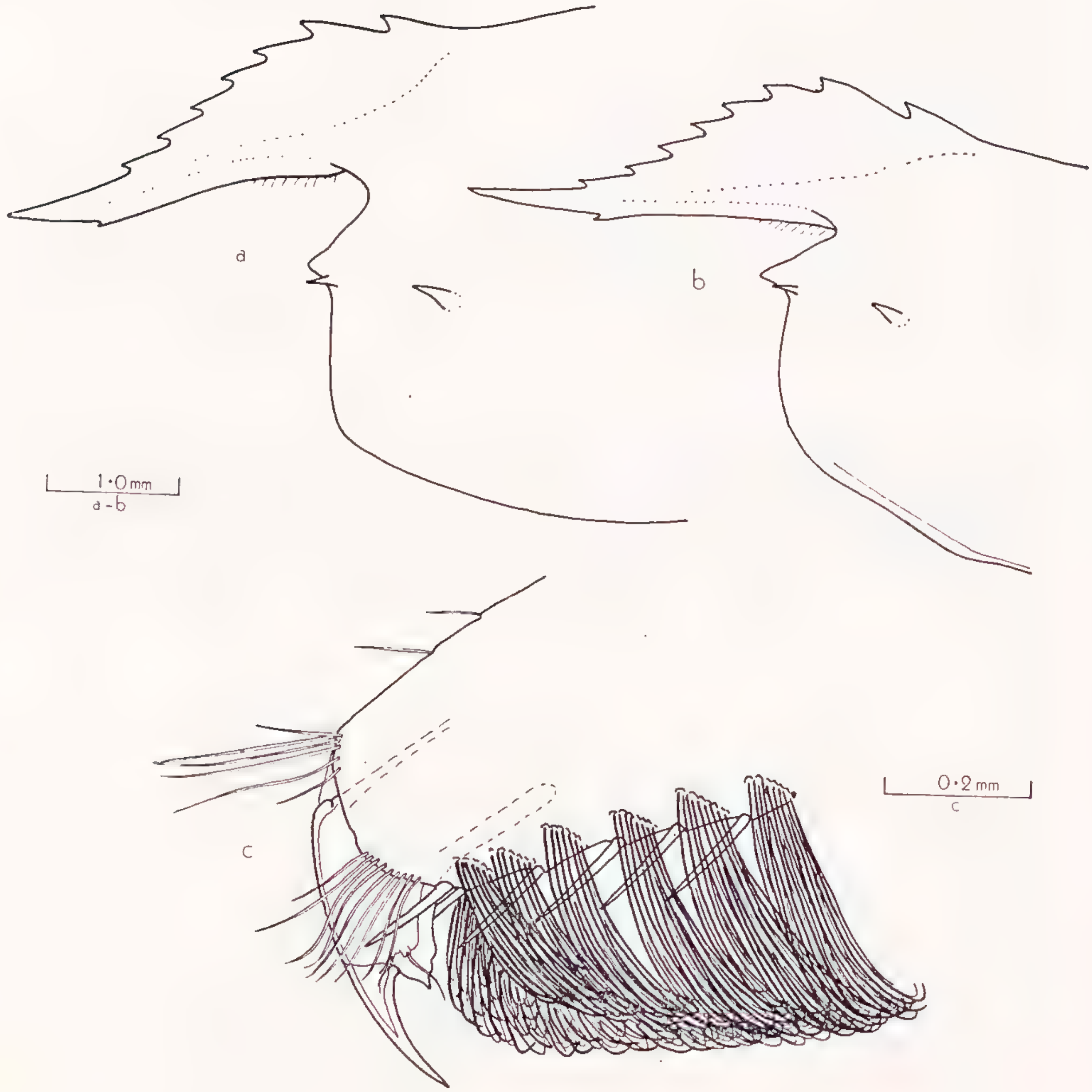


Fig. 2.—*Periclimenes colemani* sp. nov. Anterior carapace and rostrum. A, allotype female. B, holotype male. C, dactyl and distal propodus of third pereiopod of female.

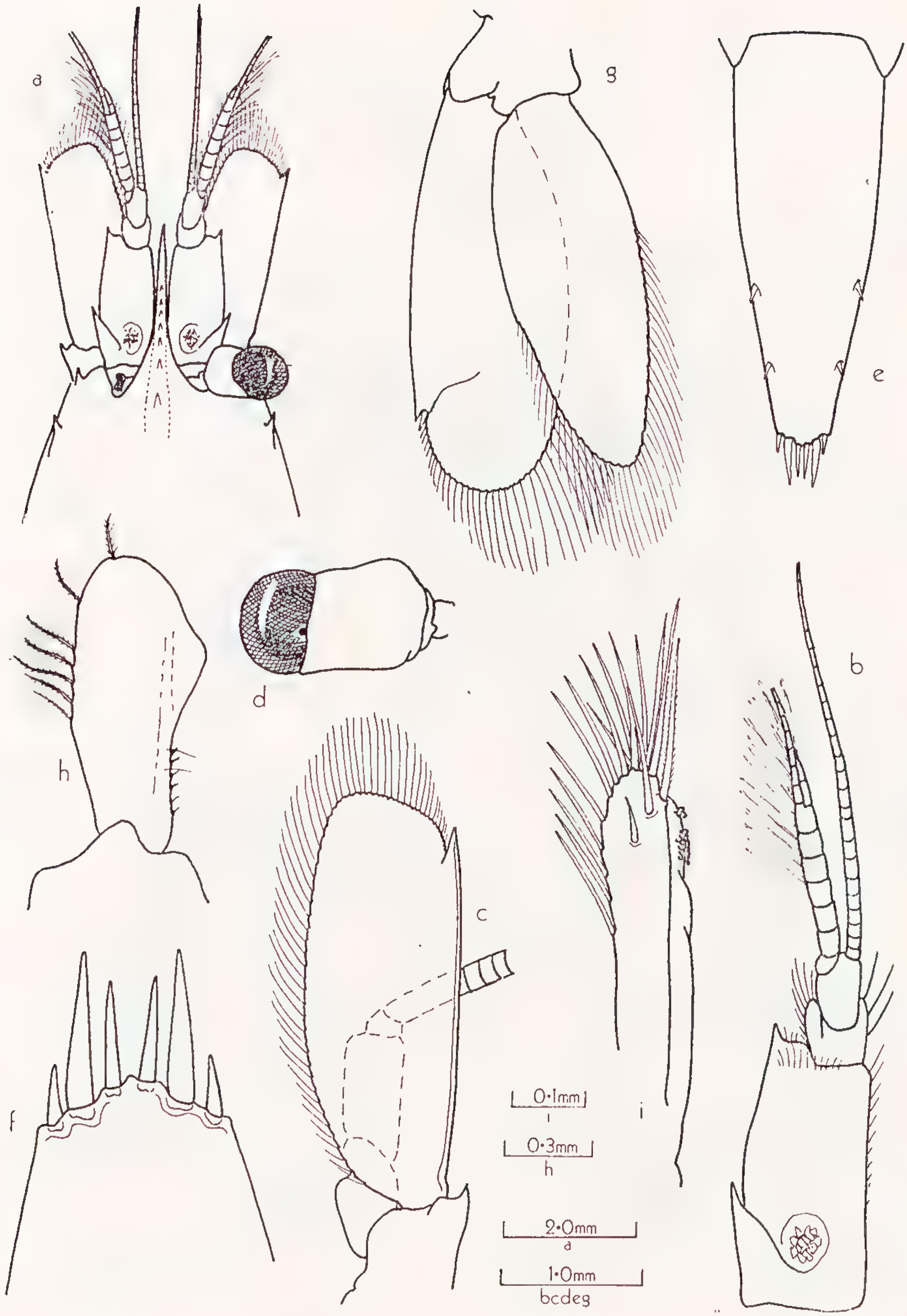


Fig. 3.—*Periclimenes colemani* sp. nov. A, anterior carapace, rostrum and antennae, dorsal view. B, antennule. C, antenna. D, eye, dorsal aspect. E, telson. F, posterior telson spines. G, uropod. H, endopod of first pleopod. I, appendix interna, appendix masculina of second pleopod. A-G, female allotype, H-I, male holotype.

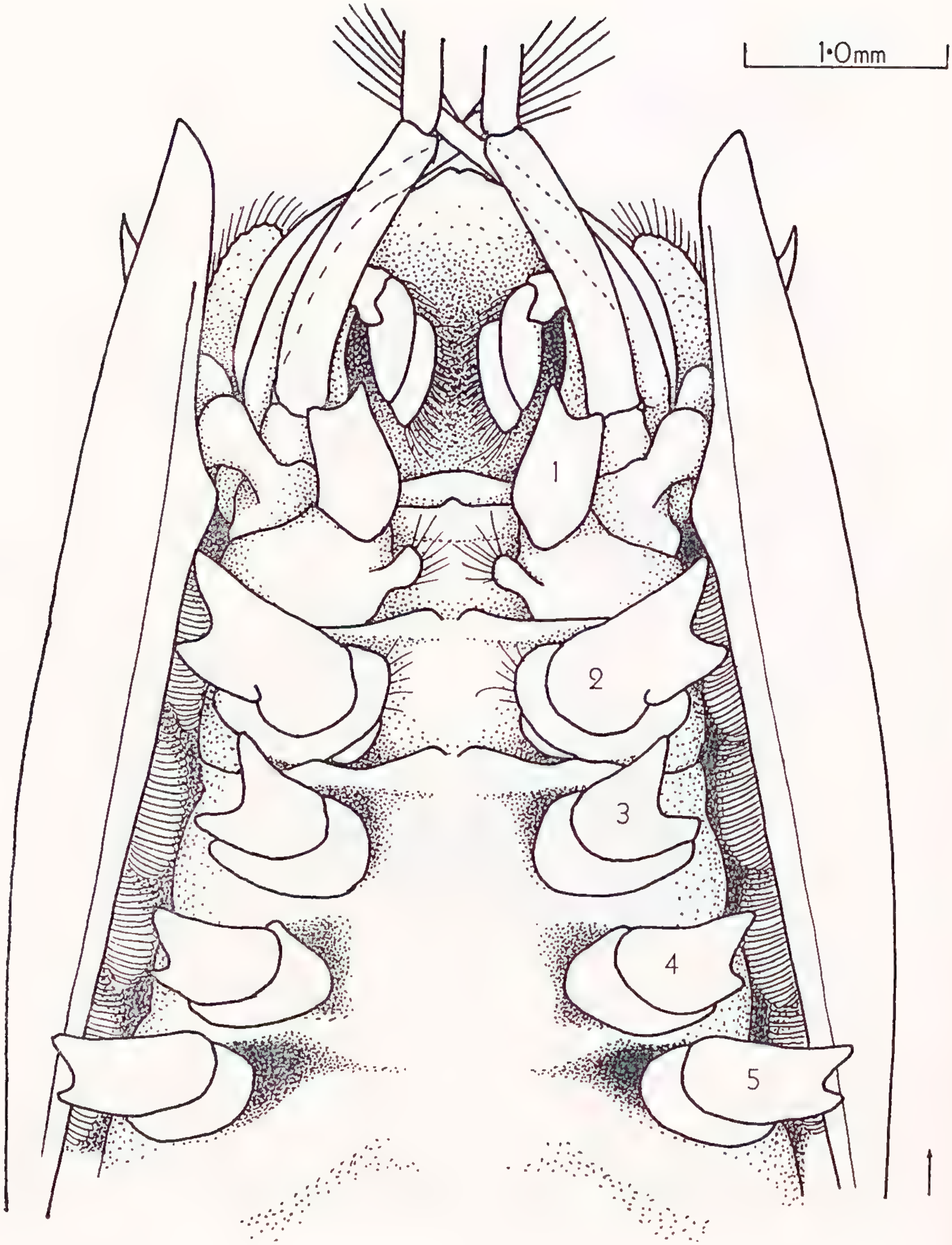


Fig. 4.—*Periclimenes colemani* sp. nov. Female allotype, thoracic sternites.

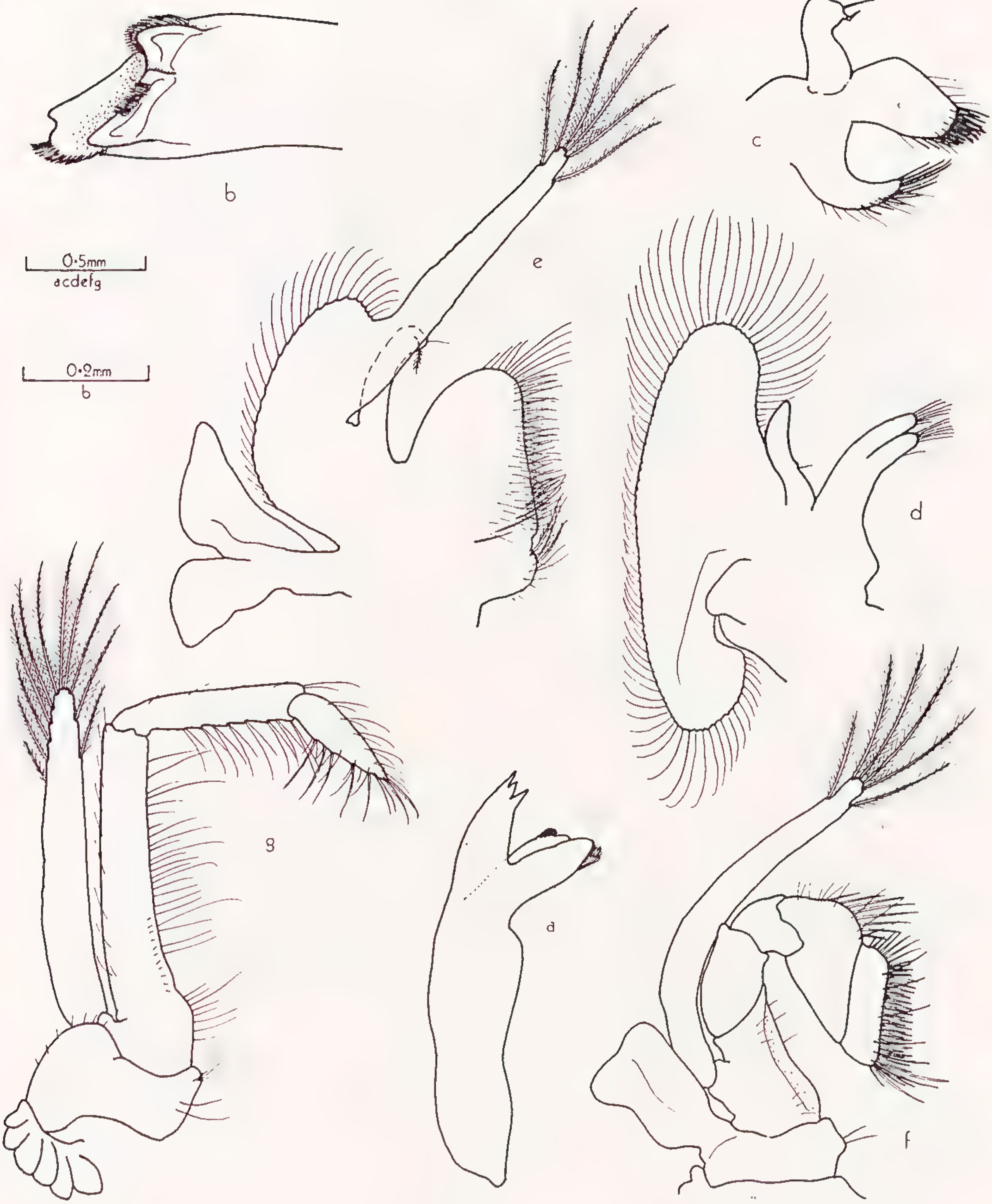


Fig. 5.—*Periclimenes colemani* sp. nov. Female allotype, mouthparts. A, mandible. B, molar process of mandible. C, maxillula. D, maxilla. E, first maxilliped. F, second maxilliped. G, third maxilliped.

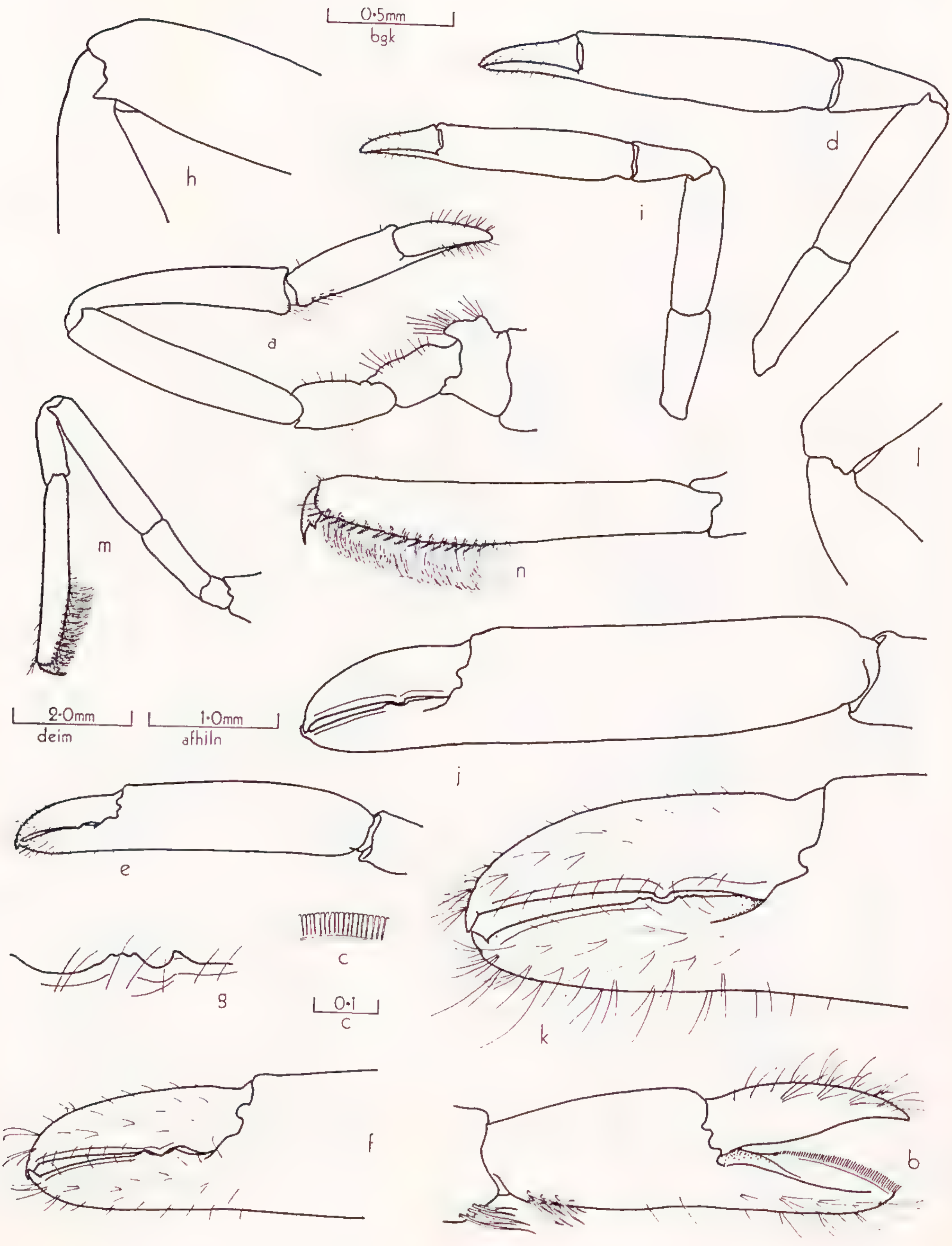
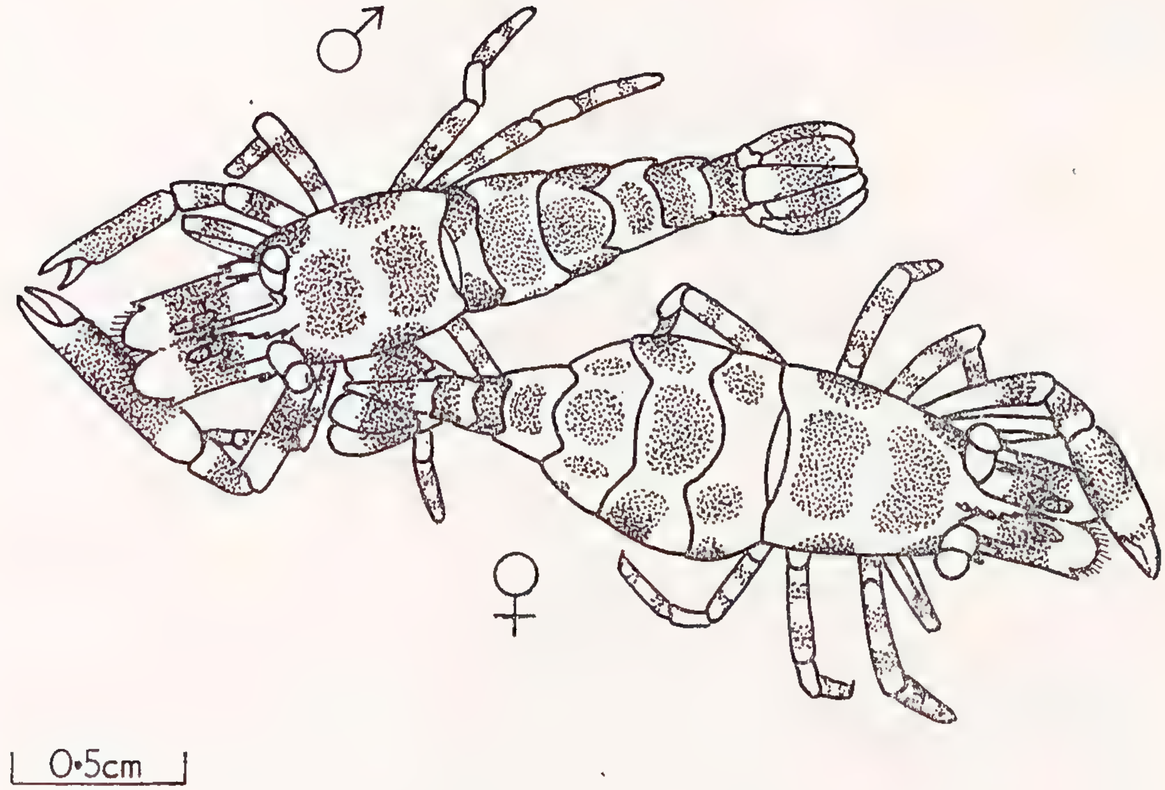


Fig. 6.—*Periclimenes colemani* sp. nov. A, first pereiopod. B, chela of first pereiopod. C, cutting edge of finger of first pereiopod. Male second pereiopod. D, major pereiopod. E, chela. F, fingers. G, teeth of fixed finger. H, carpo-meral joint. Female second pereiopod. I, major pereiopod. J, chela. K, fingers. L, carpomeral joint. M, third pereiopod of female. N. propodus and dactylus of third pereiopods.



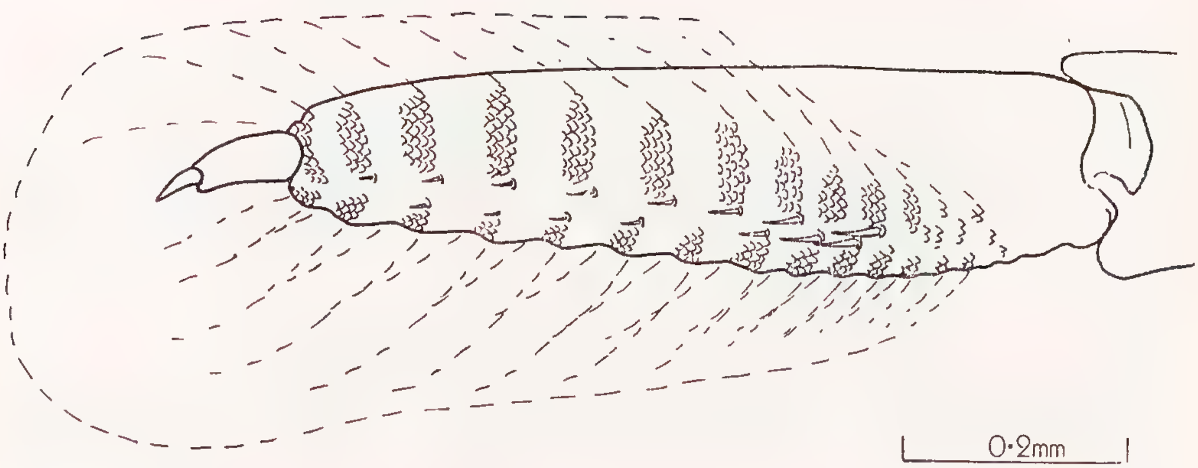


Fig. 7.—*Periclimenes colemani* Male and female. From colour photograph by N. Coleman.

Fig. 8.—*Periclimenes hirsutus* Bruce. Ventral aspect of third pereiopod of female.

AUSTRALIAN SPECIES OF *HALIOPHASMA* (CRUSTACEA: ISOPODA: ANTHURIDAE)

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Figures 1–16

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SUMMARY

Haliophasma purpureum Haswell, 1881, types species of the genus, and nine new species of *Haliophasma* (*H. canale, H. cribensis, H. cycneum, H. falcatum, H. pugnatum* and *H. yarra* from Port Phillip and Western Port Bays in Victoria; *H. elongatum* and *H. pinnatum* from the New South Wales shelf; and *H. syrtis* from Moreton Bay, Queensland) are described and figured. A key to these species is presented and their relationships discussed. The genus *Haliophasma* is redefined and the status of some of its previously included species is questioned.

INTRODUCTION

The family Anthuridae is at present known to be represented in Australia by 15 species in 9 genera. However, examination of material from recent surveys of the soft-bottom benthos in bays and coastal waters near major population centres in the southeast of the country has revealed the existence of many more species. This paper is the first of what I hope to be a series describing this group.

The genus *Haliophasma* was erected by Haswell (1881) for two species of anthurid isopod, *H. purpureum* and *H. maculatum* from Port Jackson, Australia. Barnard (1925a) placed *H. maculatum* in *Mesanthura,* leaving *H. purpureum* as type species. Twelve additional species of *Haliophasma* have subsequently been described from South Africa, West Africa, southern California, the Mediterranean Sea and Venezuela.

In this paper the type species and nine new species from Australia are described. The generic diagnosis is rewritten and a key to Australian species presented. The status of the non-Australian species is discussed.

Nomenclature used differs little from that used in Barnard's (1925a) review of the family. The maxilliped in *Haliophasma* is of 4 articles (the fused basal one not figured), the last two being equivalent to the palp in other isopods. The maxilla, as used here, is probably the outer lobe of maxilla 1 but the homology of this structure seems in doubt. All illustrations are of left mouthparts or limbs. The generic name is considered neuter.

Material of new species for this paper has come from the following surveys and institutions: Port Phillip Bay Environmental Study (PPBES) and Crib Point Benthic Survey (CPBS), Fisheries and Wildlife Division, Melbourne, Victoria; Shelf Benthic Survey (SBS), the Australian Museum, Sydney, New South Wales; Moreton Bay Benthic Survey (MBBS), Department of Zoology, University of Queensland, Brisbane, Queensland. Type material has been lodged in the museums indicated and series of *H. canale, H. cribensis, H. falcatum, H. pugnatum,* and *H. yarra* have been placed in the Australian Museum, and series of *H. elongatum* and *H. pinnatum* placed in the National Museum of Victoria.

Family **ANTHURIDAE**

Genus **Haliophasma** Haswell, 1881

Haliophasma Haswell, 1881: 476.—Barnard, 1925a: 131.—Barnard, 1940: 382.—Menzies and Barnard, 1959: 17.

Diagnosis. Anthuridae with normal, non-piercing mouthparts. Eyes well developed. Pereon with dorsolateral grooves and sometimes with additional pitting or sculpture; pereonites 4–6 with dorsal pits. Pleonites 1–5 fused, 6 distinct but not aways distinct from telson dorsally. Telson thick, more or less indurated and usually dorsally sculptured; pair of statocysts present (but not always obvious). Uropod with endopod shorter than telson, exopod folding alongside or over telson. Antenna 1 with flagellum 2-articulate, article 2 minute. Antenna 2 with flagellum of 4–7 articles. Mandible with 3-articulate palp, article 3 with 1 seta or transverse or oblique row of 2 to many setae. Maxilliped 4–articulate, article 4 smaller than 3. Pereopod 1 stout, palm entire but sometimes strongly curved. Pereopods 2, 3 with article 6 rectangular. Pereopods 4–7 with article 5 rectangular not underriding 6, dorsal margin about half as long as 6. Pleopod 1 more or less indurated, operculiform. Adult male characterized by more elongate form, less pronounced sculpture, multiarticulate setose flagellum on antenna 1, larger eye, more elongate pereopods, telson and uropods, simple appendix masculinis on pleopod 2. (Females bearing oostegites have not been reported.)

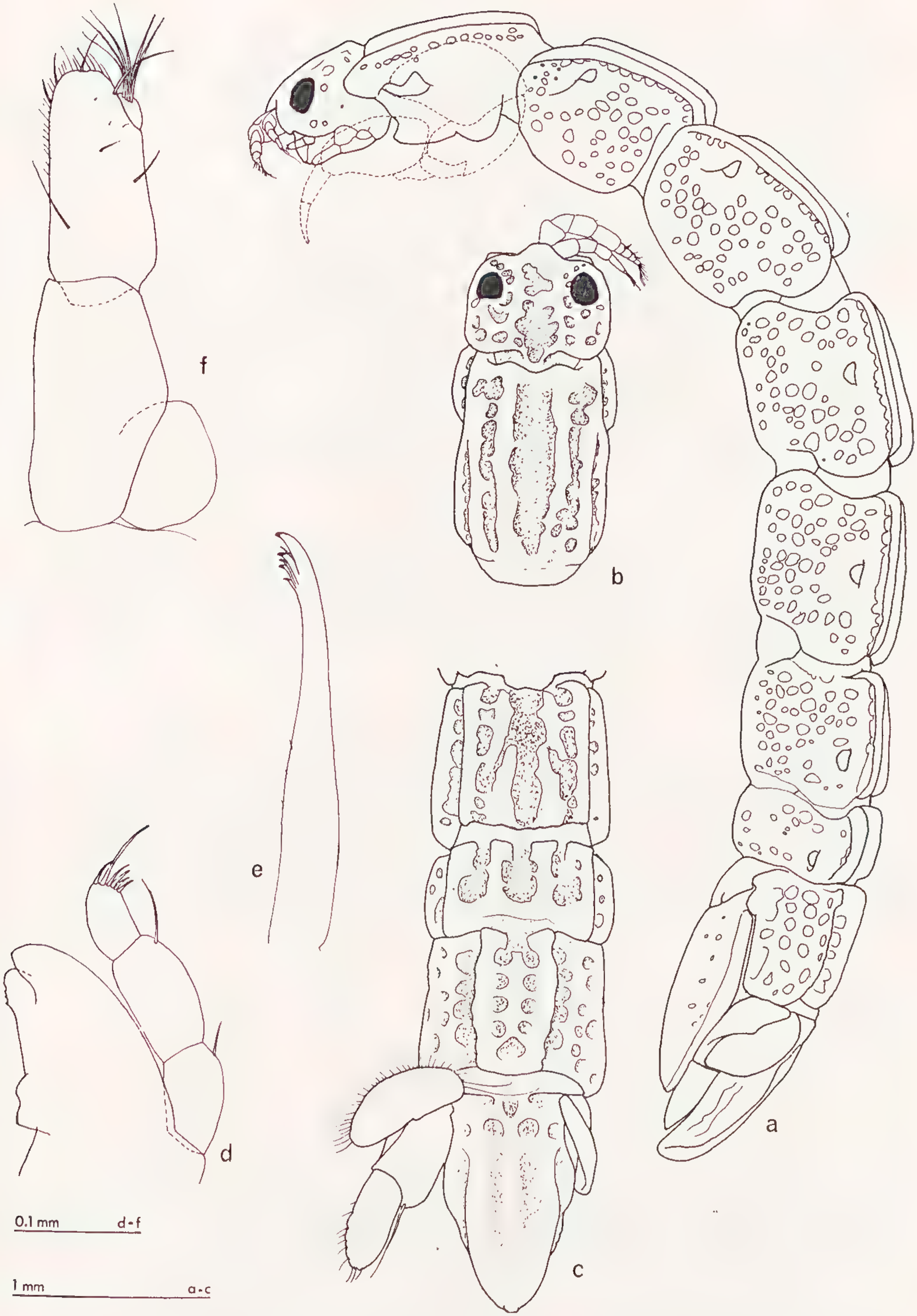

Fig. 1.—*Haliophasma canale* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, anterior end, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped.

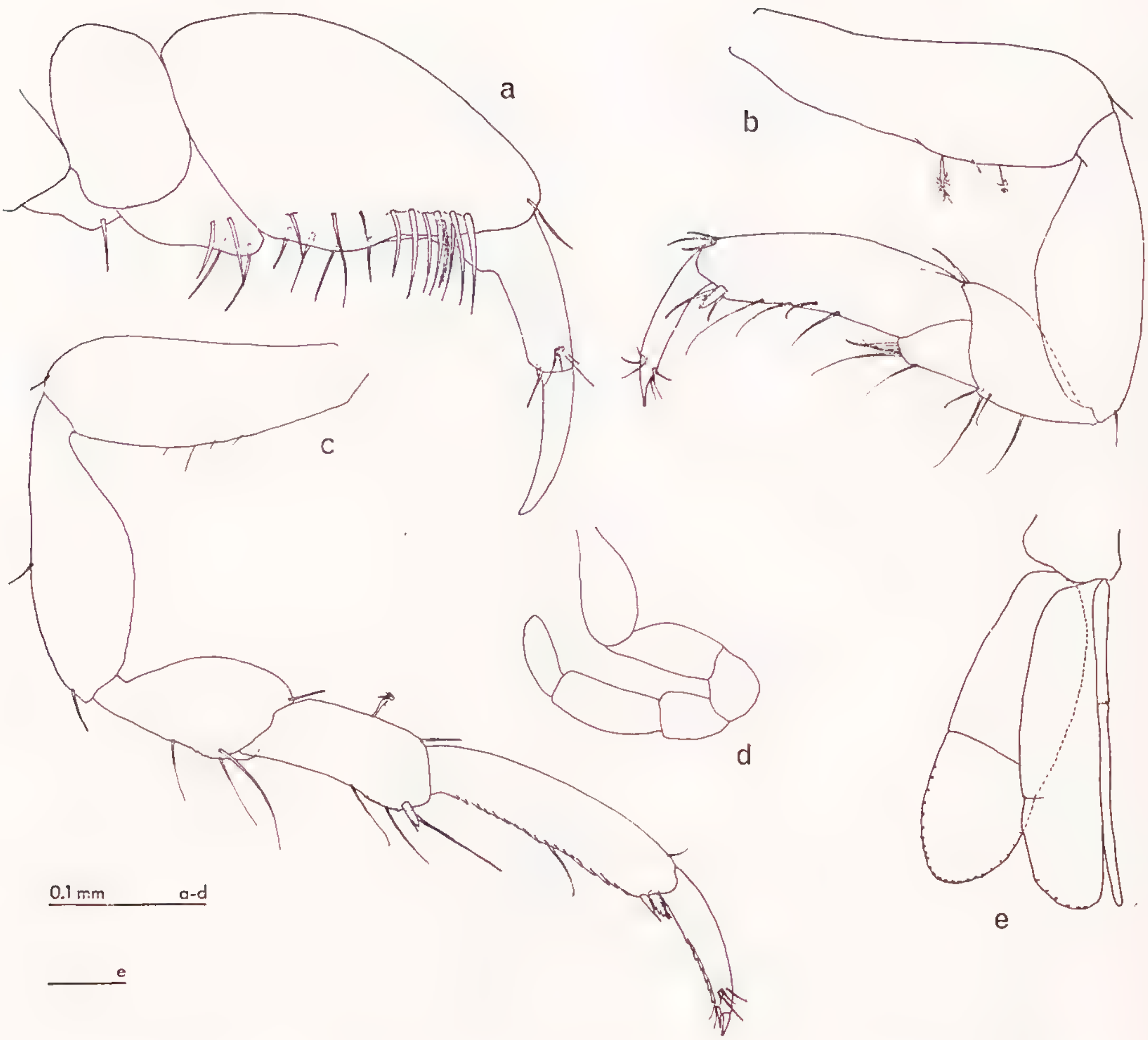

Fig. 2.—*Haliophasma canale* n. sp. Holotype: a–c, pereopods 1, 2, 7. Juvenile (5.4 mm long): d, pereopod 7. Allotype (male): e, pleopod 2.

Haliophasma canale, new species

Figures 1, 2

Description. Head wider than long, strongly pitted dorsally and laterally; prominent, broad, truncate rostrum greatly exceeding anterolateral lobes; cheek with strongly convex ventral margin; eyes dark. Pereon with strong doroslateral grooves complicated by large pits; 2 pairs of low dorsal carinae separated by a deep median groove; strongly pitted laterally. Pereonite 1 with distinctly bilobed ventral keel, produced anteriorly. Pereonites 4–6 with large, circular dorsal pits obscured by median groove. Pleonites 1–5 without epimera; laterally pitted; dorsally the medial pair of pereon carinae run on to pleon where they are separated by a short central ridge and intervening pits, lateral pair of pereon carinae obsolete. Pleonite 6 not distinct from telson mid-dorsally. Telson thick

with broad ventrolateral flanges proximally, median dorsal carina and 2 low dorsolateral ridges meeting anteriorly behind a pair of large pits; broadly rounded terminally. Uropod peduncle medially lobed; endopod not reaching to end of telson, unevenly scalloped lateral edge, medial margin convex; exopod dorsal margin evenly curved, folding alongside telson and not exceeding it dorsally, shorter than peduncle.

Antenna 2, article 2 short, dorsal flange triangular, much less than half width of front of head; flagellum of 5 articles, subequal to peduncle article 5. Mandible with a short, blunt bilobed molar; palp reaching to about end of incisor, article 2 the longest with a single long subterminal seta, article 3 broad, curved with oblique row of 6 setae. Maxilla elongate, almost straight; 5 hooks, 1 spine. Maxilliped articles 2, 3 narrow, scarcely produced laterally; article 3 truncate terminally, 3 long setae and many fine hairs on medial margin, ventral face with 1 proximal seta, 2 in the mid-area and 1 on distal suture; article 4 small, quite lateral being about its own length from distal end of article 3, bearing 6 setae. Pereopod 1 with slightly sinuous, blade-like palm on axis of limb, few medial setae and few lateral setae near palm edge; unguis 0.5 length of dactylus.

Male. Differs from above description in: less pronounced dorsal sculpture; antenna 1 setose, 17 articles, reaching back to end of pereonite 1; eye larger; pereopod 1, article 6 more elongate, palm densely setose medially; pereopods more elongate; pleopod 1 less indurated; pleopod 2 with appendix masculinis simple, more than half length of inner ramus and reaching to its end; telson flatter, more elongate; endopod of uropod longer.

Development. Ovigerous females were not found but adult males were found on 10th June, 1971, in Port Phillip Bay (stn 921), and on 6th July, 1970, at Crib Point (stn 32N). One of the males at stn 32N had a small eye, lacked setae on the otherwise male-type antenna 1, did not have a flattened telson and lacked the appendix masculinis. Juveniles up to a length of about 5 mm lack pereopod 7; pereopod 7 is reflexed forwards and has paddle-like article 7 on individuals up to about 6 mm and normal at greater lengths. Maximum size about 10 mm.

Types. National Museum of Victoria. Holotype, No. J.250, subadult 9.0 mm long. Allotype, No. J.264, male 8.7 mm long. Paratype series, No. J.266, 10 specimens.

Type locality. Port Phillip Bay, near Martha Cliff, PPBES stn 978, 19 m, clayey-silt sediment, 12th October, 1971.

Material. Port Phillip Bay, PPBES stns: 908 (1 specimen), 921 (10), 932 (1), 978 (1); Western Port Bay, Crib Point, CPBS stns: C2 (1), C3 (2), 11N (1), 22N (1), 22S (1), 26N (1), 300 (1), 31N (3), 31S (2), 32N (7), 33N (1), 34N (2), 40E (2), 51N (1), 51S (1), 61N (2).

Distribution. Port Phillip and Western Port Bays, Victoria; 3–19 m; clayey-silt to coarse sand sediments.

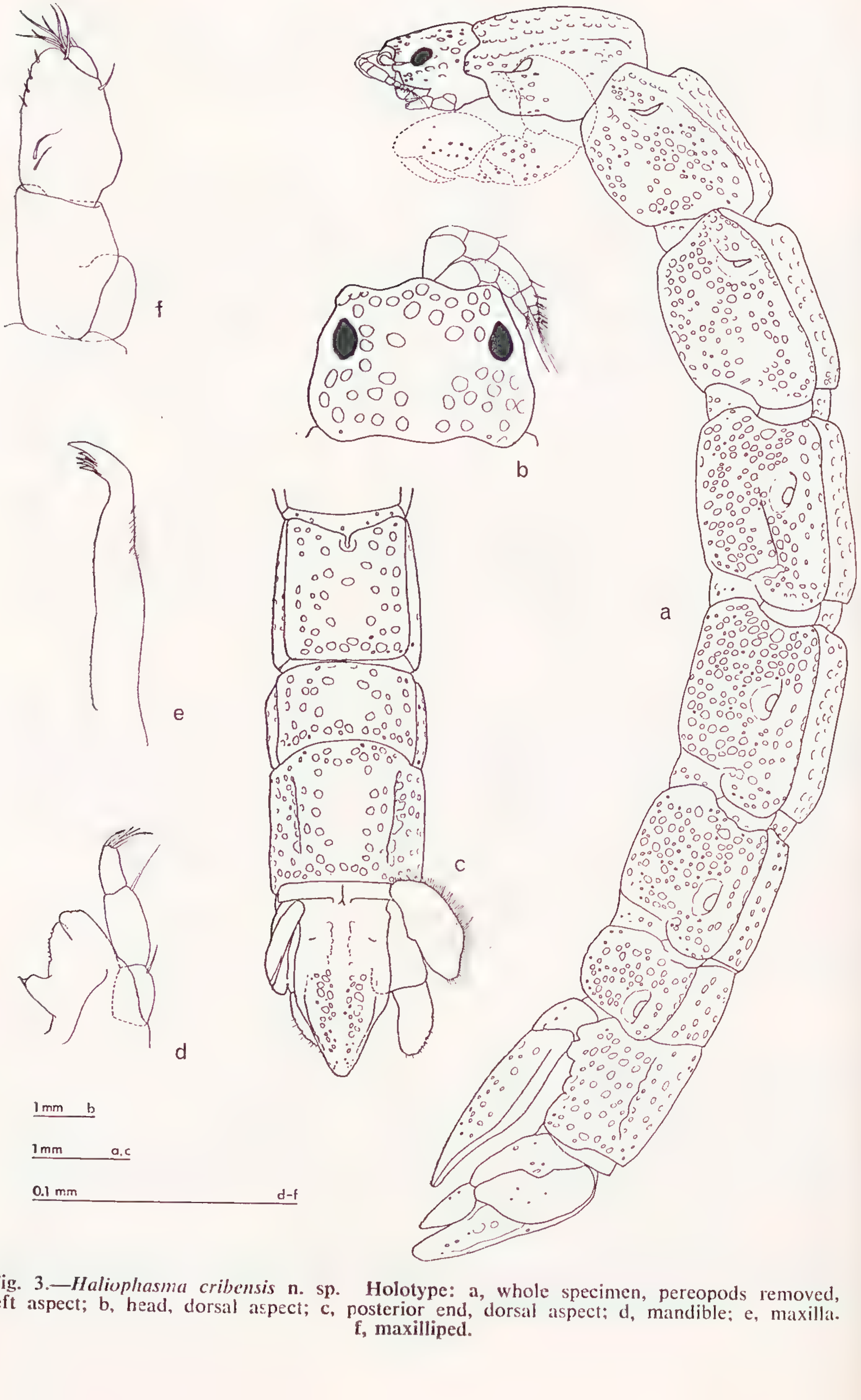

Fig. 3.—*Haliophasma cribensis* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla. f, maxilliped.

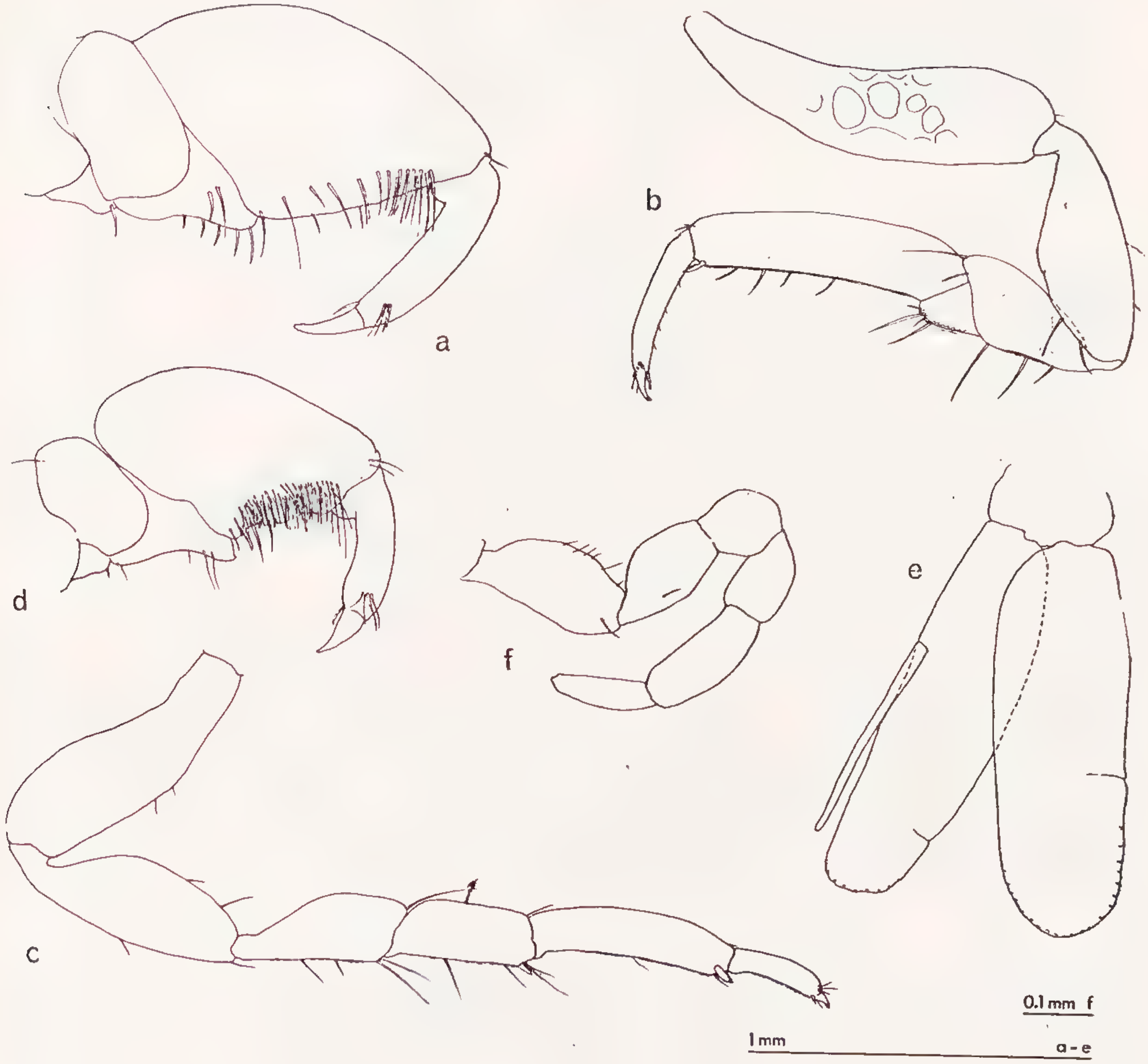

Fig. 4.—*Haliophasma cribensis* n. sp. Holotype: a–c, pereopods 1, 2, 7. Allotype (male): d, pereopod 1; e, pleopod 2. Juvenile (6.1 mm long): f, pereopod 7.

Haliophasma cribensis, new species

Figures 3, 4

Description. Head wider than long, narrowing anteriorly, strongly pitted dorsally and laterally; rostrum very broad, bluntly rounded, little longer than anterolateral lobes; cheek definitely angular anteriorly; eyes dark. Pereon with strong dorsolateral grooves complicated by some small pits, extensively pitted dorsally and laterally. Pereonite 1 with obsoletely biblobed ventral keel, not produced anteriorly. Pereonites 4–6 with transverse step between major part of dorsal surface and lower anterior area; dorsal pit reduced to a small keyhole-shaped notch at midpoint of this step. Pleonites 1–5 with small epimera, dorsolateral groove distinct, complicated by pits and not extending back to posterior margin; pitted laterally but free of pits mid-dorsally. Pleonite 6 fused with telson at midpoint.

Telson thick; a low median carina along whole length but most prominent proximally, and smooth dorsolateral ridges on distal half, pitted dorsally between the 3 ridges and laterally; narrowly rounded terminally. Uropod peduncle with medial lobe square posteriorly; endopod not reaching to end of telson, bluntly rounded with scalloped lateral margin and concave medial margin; exopod with sinuous margin, folding alongside telson and not exceeding it dorsally, little longer than peduncle.

Antenna 2, article 2 short, dorsal flange subtriangular, much less than half width of front of head; flagellum of 6 articles, shorter than peduncle article 5. Mandible with prominent molar bearing sharp accessory tooth; palp reaching beyond incisor, article 2 the longest with a single long subterminal seta, article 3 narrow, curved, with transverse row of 4 setae. Maxilla narrow, sharply curved end; 5 hooks and 2 spines. Maxilliped articles 2, 3 broad, laterally produced; article 3 rounded terminally, 4 short setae on medial margin, ventral face with 2 proximal setae, near distal suture and 1 near outer distal edge; article 4 small, ovoid, subterminal, scarcely exceeding end of 3, with 6 setae. Pereopod 1 with straight, blade-like palm on axis of limb, few medial setae and 1–2 laterally near palm edge; unguis 0.25 length of dactylus.

Male. Differs from above description in: dorsal pits less pronounced; ocelli of eye (about 30) separate; antenna 1 setose, about 16 articles reaching back to midpoint of pereonite 1; pereopod 1 palm more densely setose medially and with slight notch proximally, article 5 produced distally as a tooth opposing the dactylus; other pereopods a little more elongate; pleopod 1 less indurated; pleopod 2 with appendix masculinis simple, more than half length of inner ramus but not reaching to its end; telson flatter and more pointed, median ridge indistinct; uropod with narrower endopod, less indurated.

Development. Ovigerous females were not found but adult males were found on 24th March, 1965, (stn 21N), 1st and 8th April, 1965, (stns 400, 31S), and 28th August, 1964 (stns A6). Juveniles up to a length of about 5 mm lack pereopod; up to about 7 mm pereopod is reflexed forwards and had a paddle-shaped article 7 and pereopod 7 is normal at greater lengths. Maximum length about 16 mm.

Types. National Museum of Victoria. Holotype, No. J.251, subadult 16.0 mm long. Allotype, No. J.265, male 12.7 mm long. Paratype series, No. J.267, 13 specimens.

Type locality. Western Port Bay, Crib Point, CPBS stn 21N, 7 m, fine sand-mud sediment, 24th March, 1965.

Material. Western Port Bay, Crib Point, CPBS stns: A6 (1 specimen), B6 (2), 21N (2), 21S (1), 22N (1), 22S (1), 25S (2), 26N (1), 300 (3), 31N (3), 31S (7), 34N (7), 400 (1), 42N (4), 42S (2).

Distribution. Western Port Bay, Victoria; 7–15 m; fine to fairly coarse sand sediments.

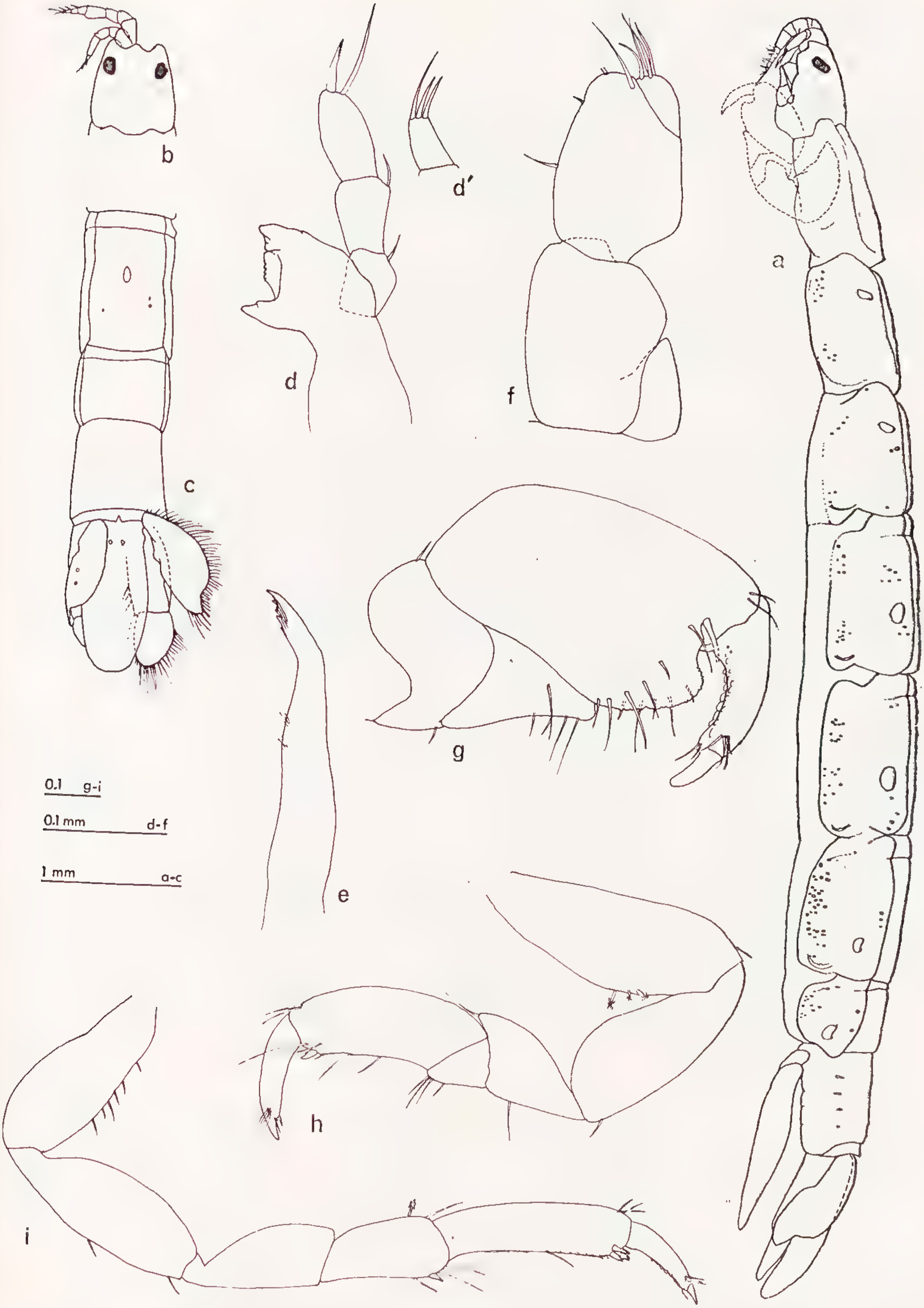

Fig. 5.—*Haliophasma cycneum* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, left mandible; d′, right mandibular palp, article 3; e, maxilla; f, maxilliped; g–i, pereopods 1, 2, 7.

Haliophasma cycneum, new species

Figure 5

Description. Head a little longer than wide, narrowing anteriorly, without pits; rostrum short, rounded, about equal to prominent anterolateral lobes; cheek deep, square anterior corner; eyes dark. Pereon with distinct, simple dorsolateral grooves, smooth except for few small pits laterally. Pereonite 1 without a ventral keel, 2 acute corners on posterior margin of dorsum. Pereonites 4–7 with a strong transverse groove anteriorly and oval dorsal pit on 4–6. Pleonites 1–5 with minute epimera, smooth except for a few pits in place of dorsolateral grooves. Pleonite 6 distinct from telson. Telson thick; smoothly curved dorsally, gently tapering to a broadly rounded end. Uropod peduncle not lobed medially but produced mediodistally; endopod as wide as peduncle, ovate not reaching to end of telson; exopods folding over telson to almost meet, produced to an acute point beyond end of peduncle.

Antenna 2, article 2 long, dorsal flange narrow, less than half width of front of head; flagellum of 5 articles, longer than peduncle article 5. Mandible with prominent molar, dominated by a large accessory tooth; palp reaching well beyond incisor, article 2 with 1 subterminal seta, article 3 narrow, curved with 3 terminal setae. (Left mandibular palp of holotype malformed—Fig. 5d.) Maxilla narrow, gently curved end; 5 hooks and 2 spines. Maxilliped articles 2, 3 broad, laterally produced; article 3 end rounded medially, 3 setae on medial margin, ventral face with 1 seta near distal suture; article 4 subterminal, reaching as far as end of 3, with 4 setae. Pereopod 1 with strongly convex blade-like palm, very few medial or lateral setae; unguis 0.25 length of dactylus.

Male. Unknown.

Holotype. National Museum of Victoria, No. J. 252, subadult 9.3 mm long.

Type locality. Port Phillip Bay, Swan Bay, PPBES stn 966, 1 m, clayey-sand sediment, 23rd January, 1973.

Material. Port Phillip Bay, Swan Bay, PPBES stn 966 (1 specimen), Western Port Bay, mudflats N. of French Island, stns M7(1), M9(1).

Distribution. Port Phillip and Western Port Bays, Victoria; shallow mudflats.

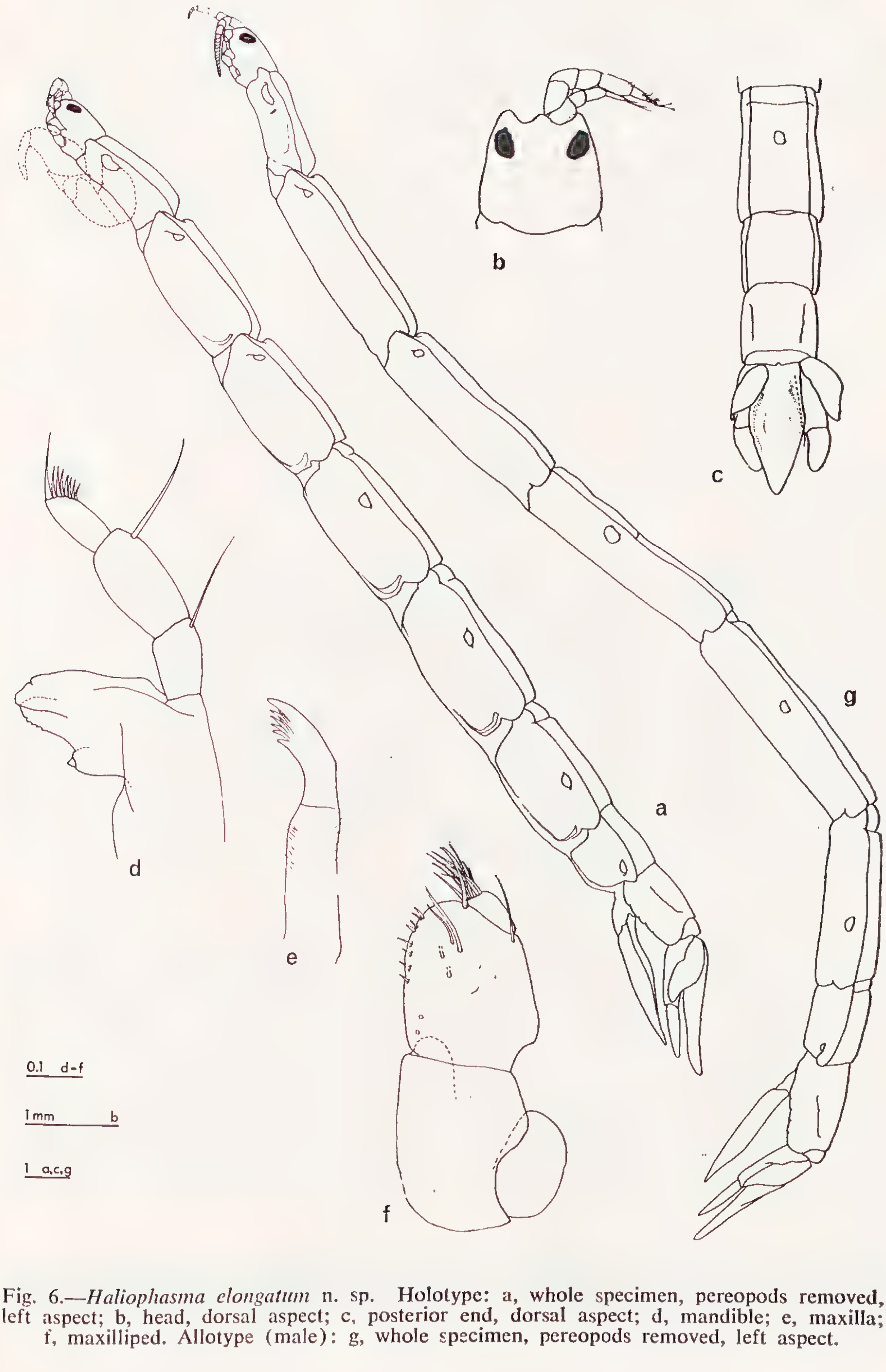

Fig. 6.—*Haliophasma elongatum* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped. Allotype (male): g, whole specimen, pereopods removed, left aspect.

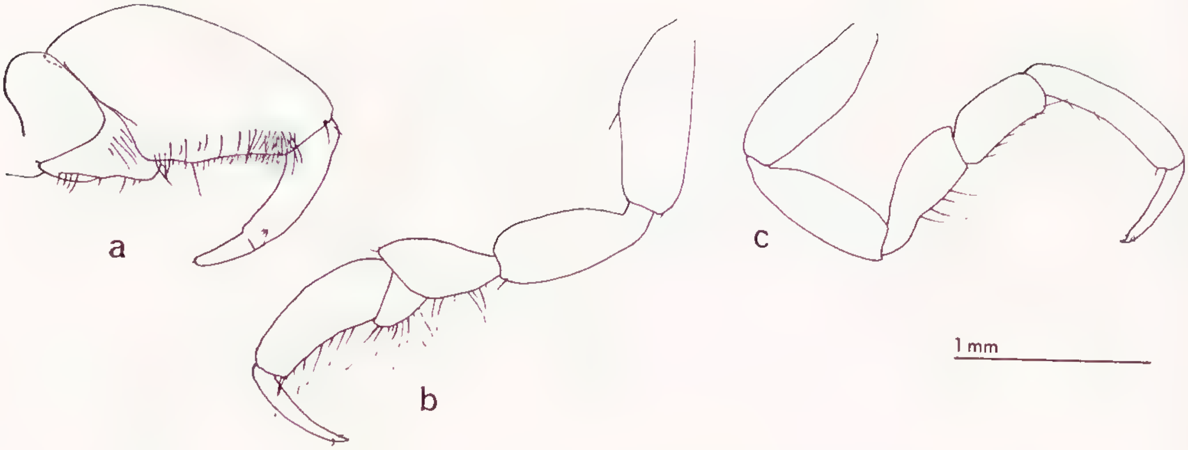

Fig. 7.—*Haliophasma elongatum* n. sp. Holotype: a–c, pereopods 1, 2, 7.

Haliophasma elongatum, new species

Figures 6, 7

Description. Head as long as maximum width, narrowing anteriorly, without pits; rostrum narrow, acute, shorter than anterolateral lobes; cheek deep, without sharp anterior corner; eyes dark. Pereon with clear, simple dorsolateral grooves, generally smooth, pitting obsolete. Pereonite 1 without ventral keel. Pereonites 4–7 with strong transverse groove anteriorly and oval dorsal pit on 4–6. Pleonites 1–5 with minute epimera, distinct dorsolateral groove, not reaching to posterior margin, otherwise smooth. Pleonite 6 distinct from telson. Telson low; sharply narrowed from midpoint to slightly upturned end; dorsal surface flat but for obsolete medial and lateral ridges vanishing posteriorly and narrowing to a broad rounded ridge anteriorly. Uropod peduncle with medial edge straight and produced a little; endopod much shorter than telson, medially concave and laterally convex; exopods not meeting over telson, strongly produced to an acute point but shorter than peduncle.

Antenna 2, article 2 long, dorsal flange broad for most of length, less than half width of front of head; flagellum of 5 articles, shorter than peduncle article 5. Mandible with a short molar bearing a small, acute accessory tooth; palp reaching well beyond incisor, article 2 the longest with a single long subterminal seta, article 3 narrow with an oblique row of 8 setae. Maxilla broad, gently curved, toothed end large; 6 hooks and 2 spines. Maxilliped articles 2, 3 broad, produced laterally; article 3 broadly rounded mediodistally, 8 short setae on medial margin, ventral face with 2 proximal setae (insertions only shown in fig. 6f), 4 in the mid-area and 3 on distal suture; article 4 subterminal but exceeding end of 3, with 9 setae. Pereopod 1 with blade-like palm on axis of limb, slight proximal convexity, densely setose medially and on lateral margin of palm; unguis 0.3 length of dactylus.

Male. Differs from above description in: antenna 1 setose, multiarticulate, reaching back to end of head; pereopod 1 palm more setose medially; pereonites 2–7, pleon, telson, uropods grossly elongate; appendix masculinis not reaching to end of pleopod 2 inner ramus.

Development. Ovigerous females were not found but adult males were found in samples taken on 23rd, 26th Jan., 22nd Feb., 26th Mar., 23rd May, 26th June, 1973. (No specimens were collected from the second half of the year). Specimens ranged from 11 mm in length to 26 mm for juveniles and females. The largest male obtained was a probable 58 mm long, as estimated from length of head plus first three segments (22 mm).

Types. Australian Museum. Holotype, No. P.20436, subadult 26 mm long. Allotype, No. P.20437, male 33 mm long. Paratype series, No. P.20438, 14 specimens.

Type locality. New South Wales shelf, off Malabar, SBS stn IV, 66 m, slightly muddy sand sediment; 24 April, 1973.

Material. New South Wales shelf, off North Head, SBS stns: 22 (2 specimens), 34 (1); off Malabar, SBS stns: 25 (5), 31 (2), 36 (1), 41 (1), III (10), IV (2), V (1), E2S4 (1).

Distribution. New South Wales shelf; 21–72 m; muddy sand to gravelly sand sediments.

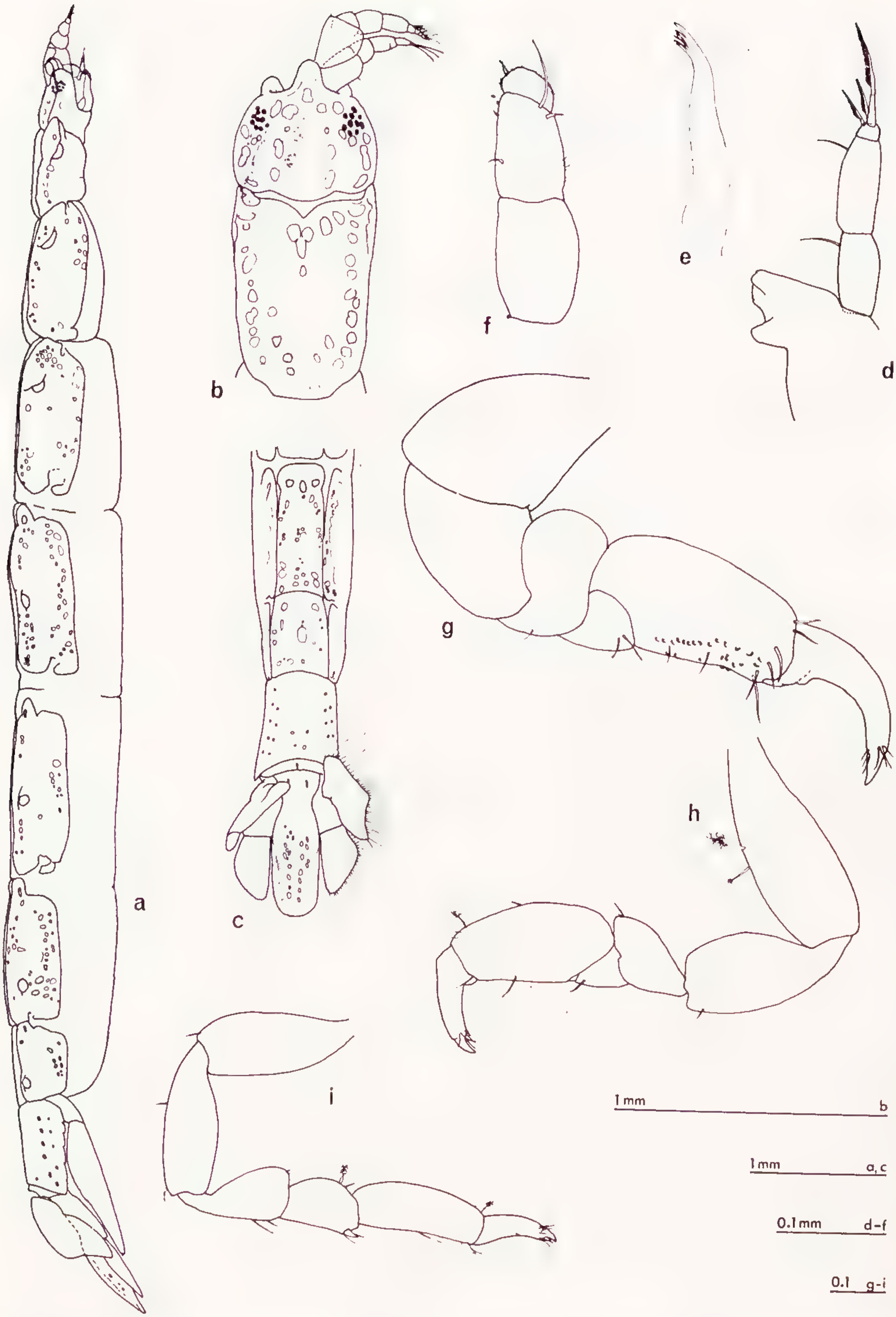

Fig. 8.—*Haliophasma falcatum* n. sp. Holotype: a, whole specimen, pereopods removed, right aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped; g–i, pereopods 1, 2, 7.

Haliophasma falcatum, new species

Figure 8

Description. Head as wide as long, convex laterally; strongly pitted laterally and dorsally; rostrum comparatively long (0.2 of total head length), gradually tapering to round end, distinctively longer than prominent anterolateral lobes; cheek with angled ventral margin; eyes with ocelli separate. Pereon with strong, simple dorsolateral grooves, pitted dorsally and laterally; dorsum flat. Pereonite 1 with a vestigial ventral keel. Pereonites 4–6 with 3 large pits in a very shallow transverse groove near anterior of dorsum. Pleonites 1–5 with minute epimera, dorsolateral groove absent except as a lateral row of pits. Pleonite 6 separate from telson. Telson dorsally convex with two longitudinal irregular rows of pits on distal two-thirds; waisted proximal third, parallel-sided distally with semicircular end. Uropod peduncle without medial lobe; endopod as long as peduncle, not reaching to end of telson, medial margin straight, widest at about midpoint and abruptly narrowing to subacute end; exopod with dorsal margin excavate posteriorly, much exceeding telson dorsally, acute posterior corner reaching well beyond end of peduncle.

Antenna 2, article 2 with a broad dorsal flange less than half width of head; flagellum of 6 articles, shorter than peduncle article 5. Mandible with a prominent blunt molar lacking accessory tooth; palp reaching beyond incisor, article 2 longest with 1 subterminal seta, article 3, minute, bearing 3 terminal setae. Maxilla narrow, gently curved; 5 hooks and 1 spine. Maxilliped articles 2, 3 narrow, not laterally produced; article 3 not produced mediodistally, single seta on medial margin, ventral face with 1 proximal seta and 2 near distal suture; article 4 terminal, its suture oblique, large, about one third length of article 3, with 2 setae and many fine hairs. Pereopod 1 with cylindrical article 6, palm straight, a convex surface, not blade-like, on axis of limb, few medial setae, 1–2 lateral setae and many small palmar hooked setae; dactylus stout, strongly curved, unguis 0.15 its length.

Male. A single specimen (length 7.7 mm) was found with male-type antenna 1 but the antenna lacked setae; the appendix masculinis was absent.

Development. Mature specimens were not found. Juveniles of length 5–6 mm had pereopod 7 reflexed. More indurated specimens differed from the holotype only in the strongly serrate margin of the uropod exopod and more pointed endopod. Maximum length recorded 9.5 mm.

Types. National Museum of Victoria. Holotype, No. J.255, subadult 9.5 mm long. Paratype series, No. J.270, 22 specimens.

Type locality. Western Port Bay, Crib Point, CPBS stn 32N, 11 m, sandy gravel sediment, 23rd March, 1965.

Material. Western Port Bay, Crib Point, CPBS stns: C2 (1 specimen), C3 (1), 21N (1), 31N (2), 31S (1), 32N (17), 32S (2), 33N (1), 51N (1), 52N (2).

Distribution. Western Port Bay, Victoria; 7–18 m; fine sand-mud sediments.

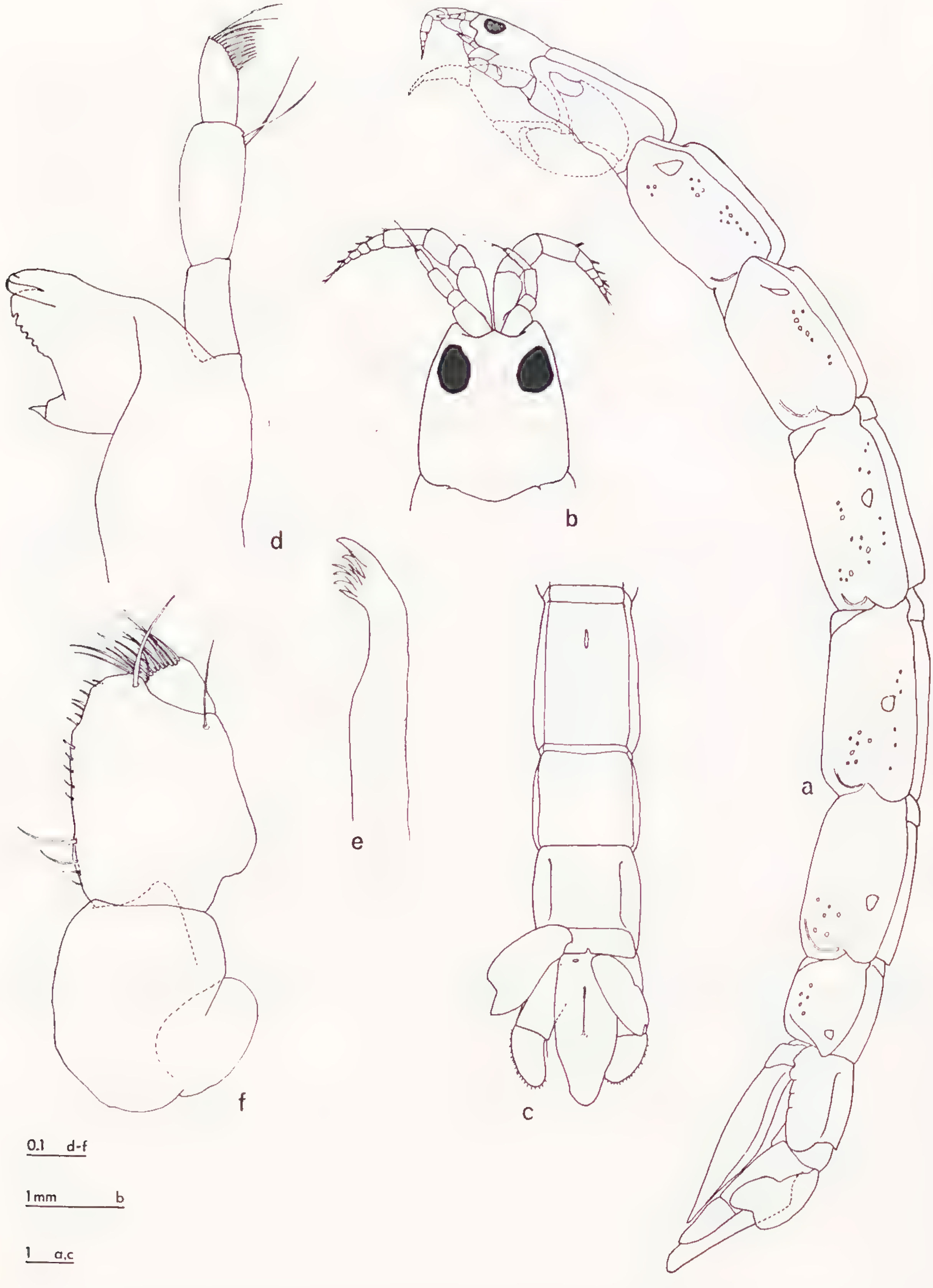

Fig. 9—*Haliophasma pinnatum* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped.

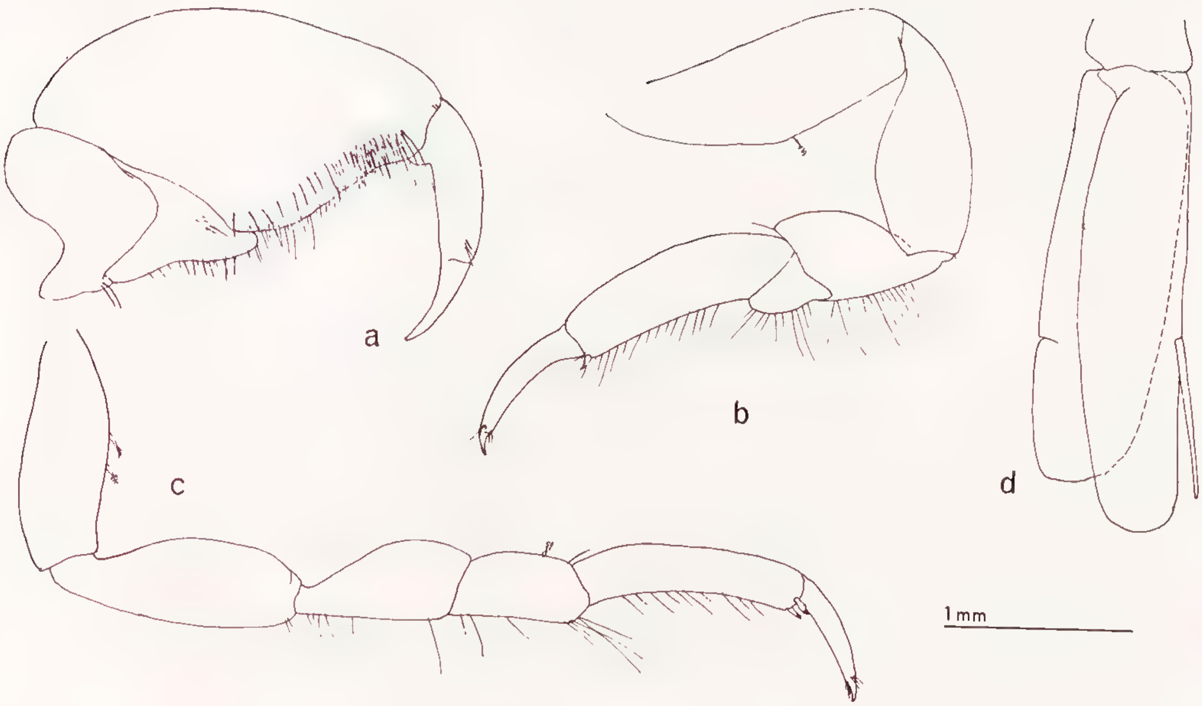

Fig. 10.—*Haliophasma pinnatum* n. sp. Holotype: a–c, pereopods 1, 2, 7. Allotype (male): d, pleopod 2.

Haliophasma pinnatum, new species

Figures 9, 10

Description. Head longer than wide, much narrower anteriorly; rostrum broad, much shorter than anterolateral lobes; cheek deep, rounded anterior margin; eyes dark. Pereon scarcely pitted, dorsolateral grooves distinct and simple. Pereonite 1 without ventral keel. Pereonites 4–7 with strong, transverse groove delineating an elevated anterior part of dorsal surface; elongate dorsal pits on 4–6. Pleonites 1–5 with small epimera, dorsolateral groove simple, extending to posterior margin. Pleonite 6 long, about 0.25 length of pleon, distinct from telson. Telson with a high narrow median crest sloping gradually posteriorly but with a steep anterior edge; narrowing to a broad, slightly upturned end. Uropod peduncle without medial lobe; endopod not reaching to end of telson, concave medial and convex lateral margins; exopods meeting dorsally over telson, basal part divided from dorsal by sharp angle on margin and produced to end of peduncle.

Antenna 2, article 2 very long, dorsal flange narrow, less than half width of front of head; flagellum of 5 articles, longer than peduncle article 5. Mandible with prominent molar bearing sharp accessory tooth; palp much longer than incisor, article 2 the longest bearing 2 long subterminal setae, article 3 narrow with an oblique row of 13 setae. Maxilla broad, large end with 6 hooks and 2 spines. Maxilliped articles 2, 3 very broad, much produced laterally; article 3

angular terminally, medial margin with 12 short setae distally and 4 longer setae proximally, ventral face with 2 setae near distal suture; article 4 triangular, subterminal, exceeding end of 3, with 11 setae. Pereopod 1 with sinuous, blade-like palm on axis of limb, densely setose medially and laterally near palm edge; unguis 0.35 length of dactylus.

Male. Differs from above description in: multiarticulate antenna 1 (broken in single specimen available), setose palm on pereopod 1; longer, flatter telson, appendix masculinis 0.35 length of inner ramus of pleopod 2 and not reaching to its end.

Development. A single male specimen, 30 mm long, was taken from stn 34 on 27th February, 1973; maximum size of non-males 28 mm.

Types. Australian Museum. Holotype, No. P.20439, subadult 22 mm long. Allotype, No. P.20440, male 30 mm long. Paratype series, No. P.20441, 5 specimens.

Type locality. New South Wales shelf, off North Head, SBS stn 22, 66 m, medium coarse sand sediment, 23rd January, 1973.

Material. New South Wales shelf, off North Head, SBS stns: 20 (4 specimens), 21 (1), 22 (1), 34 (1); off Malabar, SBS stn D2S4 (1).

Distribution. New South Wales shelf; 46–66 m; medium fine to medium coarse sand sediments.

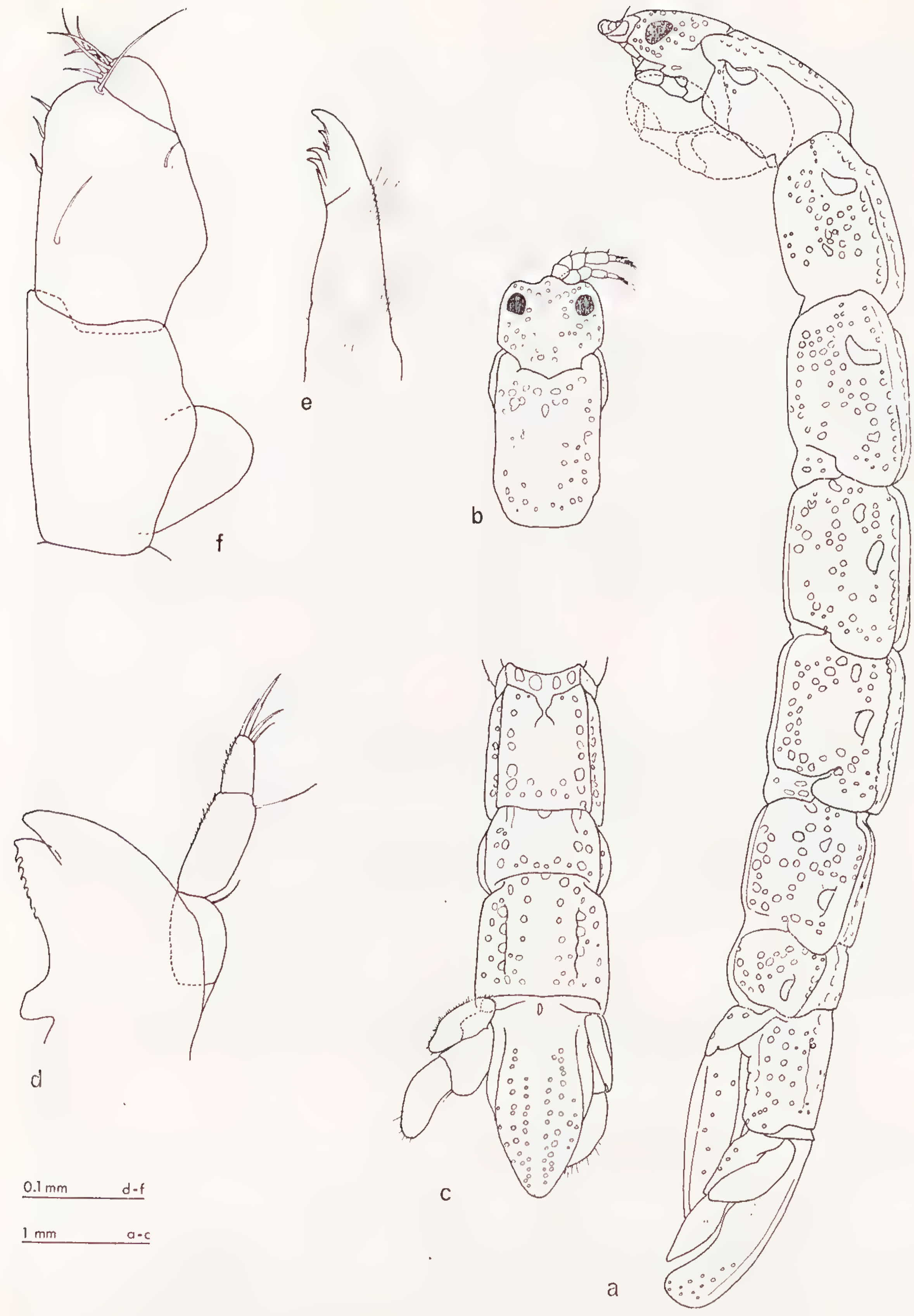

Fig. 11.—*Haliophasma pugnatum* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, anterior end, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped.

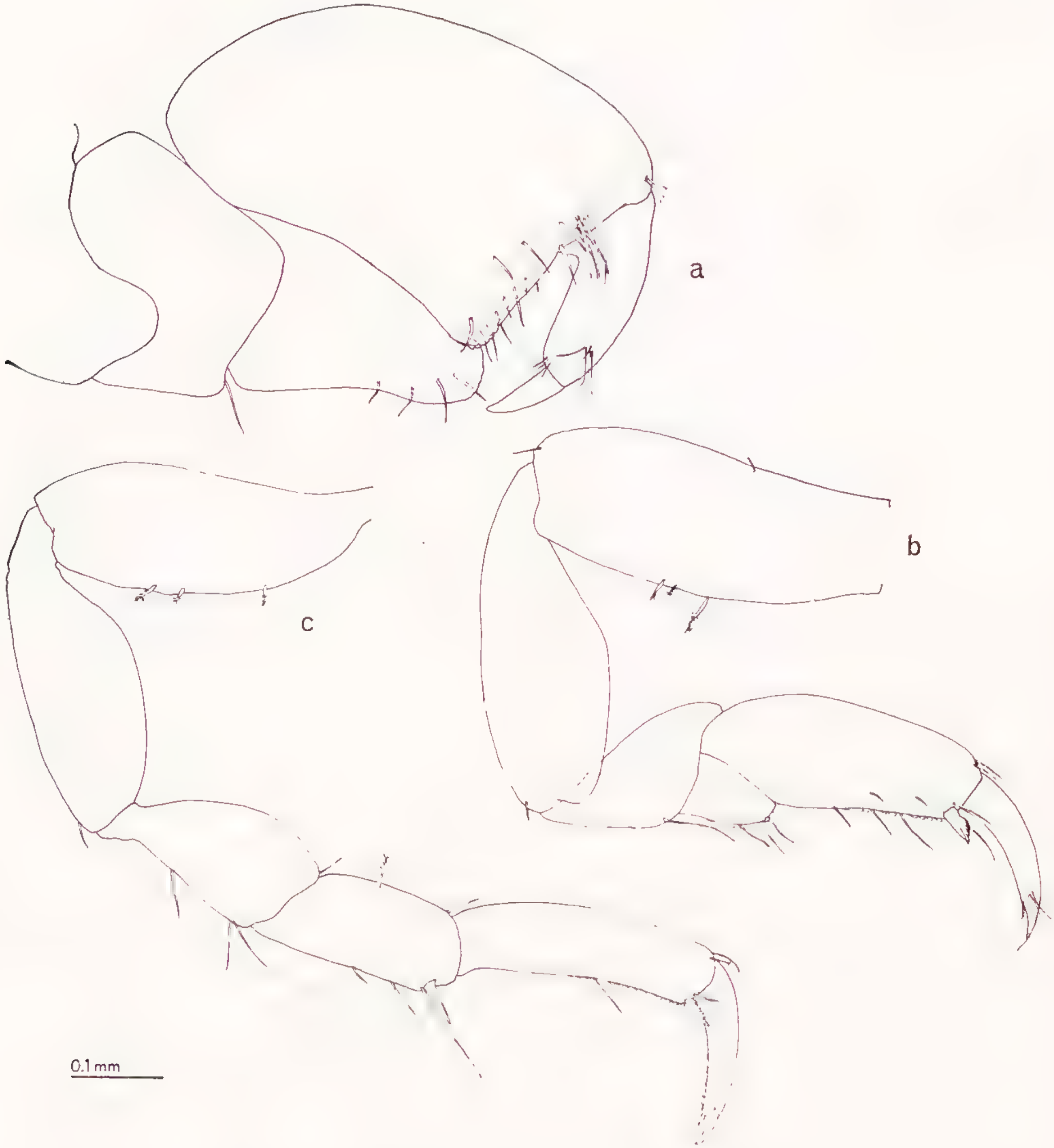

Fig. 12.—*Haliophasma pugnatum* n. sp. Holotype: a–c, pereopods 1, 2, 7.

Haliophasma pugnatum, new species

Figures 11, 12

Description. Head wider than long, strongly pitted dorsally and laterally; rostrum broad, rounded-truncate, longer than anterolateral lobes; cheek not distinct from lobes, shallowly curved ventral margin; eyes dark. Pereon with strong dorsolateral grooves complicated by pitting, extensively pitted dorsally and laterally. Pereonite 1 with obsoletely bilobed ventral keel, not produced anteriorly. Pereonites 4–6 with transverse step between major part of dorsal surface and the anterior depressed area which bears 4 large pits; dorsal pit a large keyhole-shaped notch

at midpoint of this step. Pleonites 1–5 with small epimera, dorsolateral groove distinct, complicated by pits and not reaching back to posterior margin; pitted laterally but free of pits mid-dorsally. Pleonite 6 not separate from telson mid-dorsally. Telson thick, especially terminally; 3 similar, low, smooth ridges (1 median, 2 lateral) separated by wide shallow, pitted depressions along most of length of telson and meeting anteriorly on a smooth plane; deep, elongate slit at base of this plane near fusion with pleonite 6; narrowly rounded terminally. Uropod peduncle with a rounded medial lobe, endopod not reaching to end of telson, elongate, sharply rounded terminally, concave medial margin; exopods much exceeded by telson dorsally and widely separate, dorsal margin sinuous, rounded posteriorly, little longer than peduncle.

Antenna 2, article 2 very short, dorsal flange rounded, much less than half width of front of head; flagellum of 6 articles, shorter than peduncle article 5. Mandible with a prominent, blunt molar lacking accessory tooth; palp reaching to about end of incisor, article 2 the longest with a single subterminal seta, article 3 narrow with a transverse row of 4 setae. Maxilla very stout, tapering to an almost straight, large toothed end; 5 hooks and 2 spines. Maxilliped articles 2, 3 broad, laterally produced; article 3 rounded terminally, 3 setae on medial margin, ventral face with 1 proximal seta, 1 on distal suture and 1 near outer distal corner; article 4 large, oval, subterminal, well exceeding 3, with 5 setae. Pereopod 1 with straight, blade-like palm, strongly inclined to axis of limb, few medial setae and lateral setae near palm edge; dactylus stout, unguis 0.25 its lenth.

Male. Unknown.

Development. Mature specimens were not found. A single juvenile (length 5 mm) lacking pereopod 7 was found at stn 41N. Maximum size recorded 11.4 mm.

Types. National Museum of Victoria, Holotype No. J.253, subadult, 11.4 mm long. Paratype series, No. J.268, 2 specimens.

Type locality. Western Port Bay, Crib Point, CPBS stn 25S, 8 m, muddy sand sediment, 25th February, 1965.

Material. Western Port Bay, Crib Point, CPBS stns: 03S (3 specimens), 25S (1), 41N (1), 51S (1).

Distribution. Western Port Bay, Victoria; 0–16 m; muddy to coarse sand sediments.

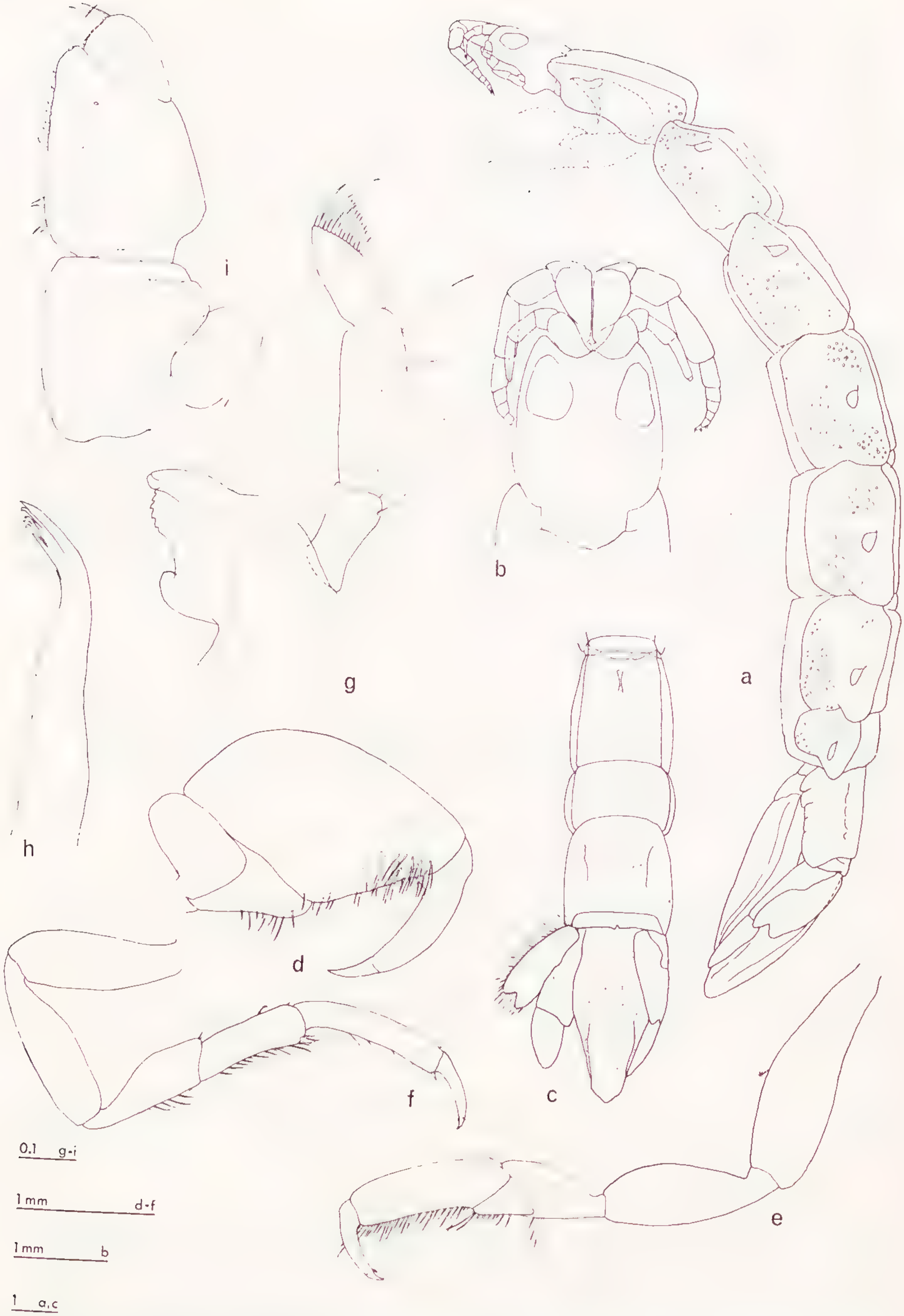

Fig. 13.—*Haliophasma purpurem* Haswell, 1881. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d–f, pereopods 1, 2, 7; g, mandible; h, maxilla; i, maxilliped.

Haliophasma purpureum Haswell, 1881

Figure 13

Haliophasma purpurea Haswell, 1881: 447; Pl. 18, fig. 3 (not fig. 2).—Haswell, 1882: 305–6.—Barnard, 1925a: 132; Pl. 4, fig. 3.

H. purpureum.—Haswell, 1884: 1012; Pl. 53, figs 6, 7.

Description. (Queries in this description result from the age of the material.) Head much longer than wide, lateral margins curving, narrower anteriorly, smooth; rostrum short, broad, a rounded point shorter than anterolateral lobes; cheek deep, angled anteriorly; eyes? Pereon with distinct, simple dorsolateral grooves, few lateral pits, Pereonite 1 without ventral keel. Pereonites 4–6 with a shallow, wide transverse groove delimiting an elevated anterior part of the dorsal surface; dorsal pit elongate, waisted. Pleonites 1–5 with clear epimera, dorsolateral groove present but not reaching to posterior margin. Pleonite 6 separate from telson. Telson thick, wih broad ventrolateral flanges proximally; 3 (1 median, 2 lateral)narrow, close ridges separated by narrow grooves, coalescing anteriorly; narrowing abruptly distally to an obtuse end. Uropod peduncle without medial lobe but medial margin produced distally; endopod not reaching to end of telson, convex on both medial and lateral margins, sharply rounded end; exopod scarcely exceeds telson dorsally, cleft posteriorly, little longer than peduncle.

Antenna 2, article 2 very long, dorsal flange little narrower than half width of front of head; flagellum of 7 articles, about as long as peduncle article 5. Mandible with a short, blunt molar with no accessory tooth; palp reaching well beyond incisor, article 2 the longest, bearing 1 subterminal and 1 lateral setae, article 3 lanceolate, with an almost-axial row of 13 setate. Maxilla narrow, gently curved; 6 hooks and ? 1 spine. Maxilliped articles 2, 3 broad produced laterally; article 3 with subacute end, ? 11 short setae on medial margin, ventral face with 2 setae in mid-area (insertions only shown in fig. 13i) and 1 terminally near distal suture; article 4 very large, ovoid-triangular, subterminal, greatly exceeding 3, with ? 8 setae. Pereopod 1 with an almost-straight, blade-like palm on axis of limb, densely setose medially and a few lateral setae near palm; unguis 0.25 length of dactylus.

Male. Unknown.

Development. Largest specimen 29 mm long.

Holotype. Australian Museum No. 526, subadult 25 mm long.

Type locality. Port Jackson (Sydney Harbour).

Material. Australian Museum Collection: holotype; P. 3314 (3 specimens).

Distribution. Port Jackson, New South Wales.

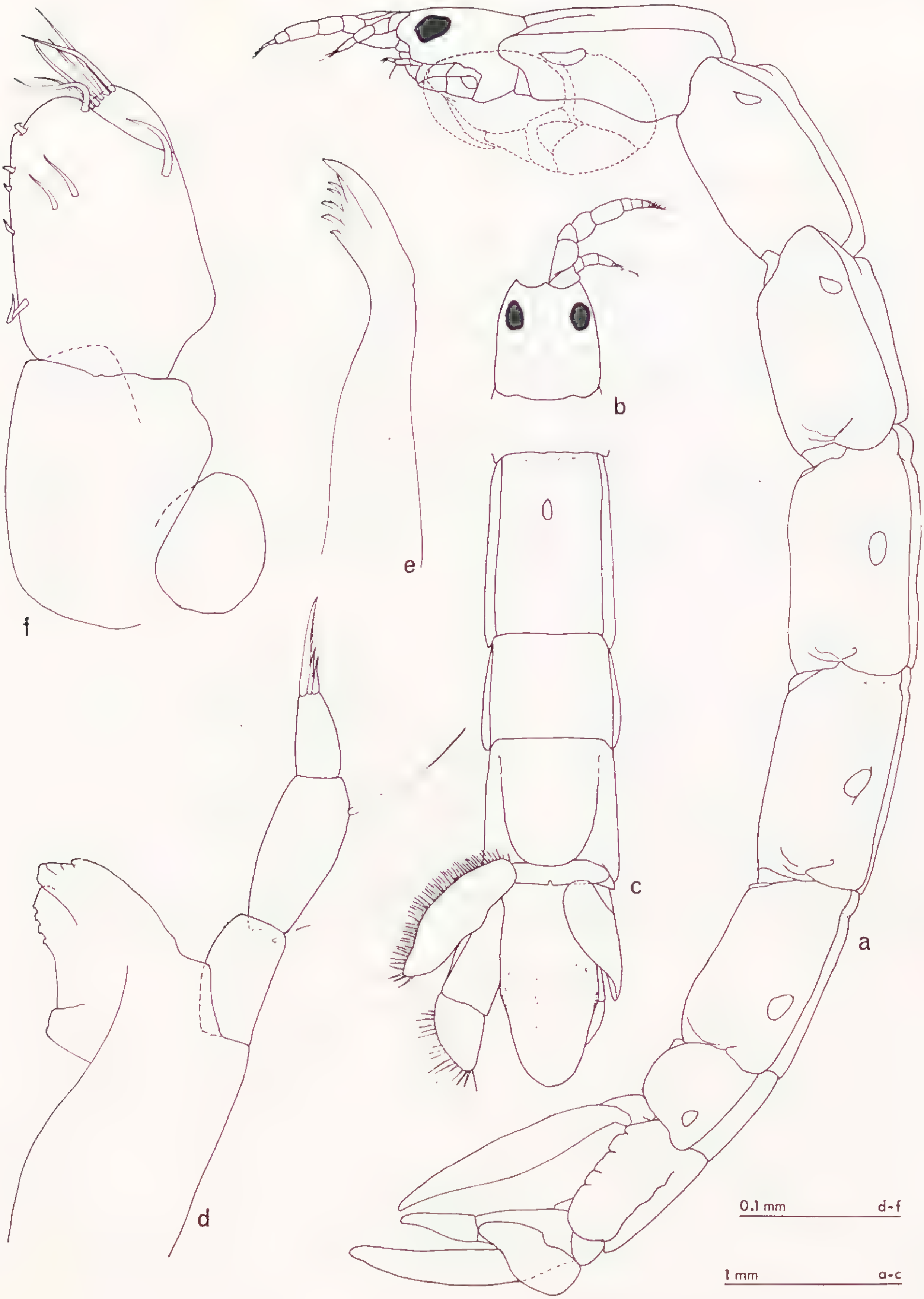

Fig. 14.—*Haliophasma syrtis* n. sp. Holotype: a, whole specimen, pereopods removed, left aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d, mandible; e, maxilla; f, maxilliped.

Haliophasma syrtis, new species

Figures 14, 15

Fig. 15.—*Haliophasma syrtis* n. sp. Holotype: a–c, pereopods 1, 2, 7.

Description. Head little longer than wide, scarcely tapering except anteriorly; rostrum broad, acute subequal to anterolateral lobes; cheek deep, rounded anterior margin; eyes dark. Pereon with clear, simple dorsolateral grooves, not pitted but surface uneven. Pereonite 1 without ventral keel. Pereonites 4–6 with a shallow, anterior transverse groove and separate oval dorsal pit. Pleonites 1–5 with distinct dorsolateral groove running into the posterior margin. Pleonite 6 separate from the telson. Telson with 2 obsolete depressions dorsally, separating very low median and lateral ridges near the midpoint, these not distinct on proximal half and coalescing distally; tapering to a broadly rounded end. Uropod peduncle without a medial lobe; endopod not reaching to end of telson, medial margin straight, lateral margin convex; exopods with sinuous dorsal margins meeting dorsally over telson, reaching to end of peduncle.

Antenna 2, article 2 long, dorsal flange broadly curved, less than half width of front of head; flagellum of 7 articles, subequal to peduncle article 5. Mandible short, lacking accessory tooth, palp extending well beyond incisor, article 2 the longest, with 1 long subterminal seta, article 3 narrow, with 3 terminal setae. Maxilla broad, gently curved to large toothed end; 6 hooks and 1 spine. Maxilliped articles 2, 3 broad, laterally produced; article 3 with rounded end, medial margin with 4 short setae and 1 long seta proximally, ventral face with 2 setae in mid-area and 2 near distal suture; article 4 small, subterminal, scarcely exceeding 3, with 5 setae. Pereopod 1 with a slightly convex, blade-like palm, few medial setae and some laterally near palm edge; unguis 0.4 length of dactylus.

Male. Unknown.

Holotype. Australian Museum No. P.20442; subadult 9.5 mm long.

Type locality. Moreton Bay, Middle Banks off Tangalooma, MBBS stn 37, 12.5 m, clean sand, 9th December, 1972.

Material. The holotype.

Distribution. Moreton Bay, Queensland; shallow sandy sediments.

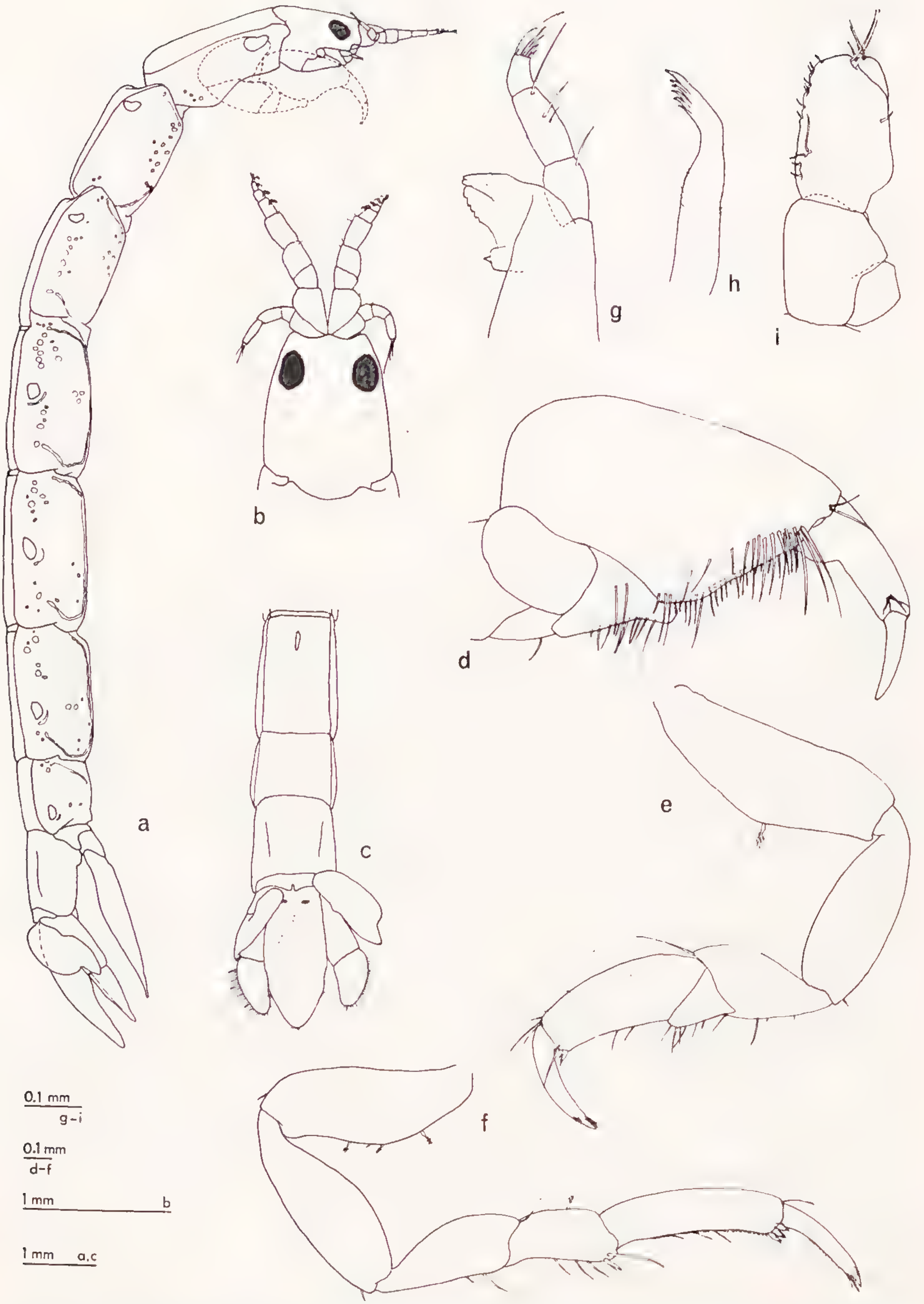

Fig. 16.—*Haliophasma yarra* n. sp. Holotype: a, whole specimen, pereopods removed, right aspect; b, head, dorsal aspect; c, posterior end, dorsal aspect; d–f, pereopods 1, 2, 7; g, mandible; h, maxilla; i, maxilliped.

Haliophasma yarra, new species

Figure 16

Description. Head much longer than wide, narrowing anteriorly, not pitted; rostrum very broad and short, as long as anterolateral lobes; cheek with a straight ventral margin, sharp anterior corner; eyes dark. Pereon with distinct simple dorsolateral grooves, with few lateral pits. Pereonite 1 without ventral keel. Pereonites 4–6 with an anterior transverse groove close to preceding segment; elongate dorsal pit. Pleonites 1–5 with shallow dorsolateral groove not extending back to posterior margin. Pleonite 6 distinct from telson and elevated from it. Telson with a smooth dome on the distal half flattening posteriorly and tapering to a bluntly rounded medial ridge anteriorly. Uropod peduncle without a medial lobe; endopod not reaching to end of telson, medial margin straight, convex lateral margin; exopods meeting mid-dorsally over telson, produced to an acute apex separated from dorsal part by a sharp angle, longer than peduncle.

Antenna 2, article 2 long, dorsal flange little narrower than half width of front of head; flagellum of 5 articles, about as long as peduncle article 5. Mandible with a short molar bearing a small accessory tooth; palp much longer than incisor, article 2 longest bearing 1 long subterminal seta and 2 lateral setae, article 3 narrow, curved, with a transverse row of 6 setae. Maxilla narrow, sharply curved; 6 hooks and 1 spine. Maxilliped articles 2, 3 broad, produced laterally; article 3 almost truncate terminally, medial margin with 10 short setae, ventral face with 2 proximal setae and pair + 1 near distal suture; article 4 small, ovoid, subterminal, level with end of 3, with 3 setae. Pereopod 1 with an almost-straight, blade-like palm on axis of limb, densely setose medially and a few setae on lateral edge of palm; unguis 0.4 length of dactylus.

Male. Unknown.

Development. Pereopod 7 was absent on specimens 5 mm long. Maximum length about 22 mm.

Types. National Museum of Victoria. Holotype, No. J. 254, subadult 15 mm long. Paratype series, J. 269, 4 specimens.

Type locality. Port Phillip Bay, Prince George Bank, PPBES stn 945, 4 m, silty sand sediment, 16th November, 1971.

Material. Port Phillip Bay, PPBES stns: 945 (7 specimens), 953 (1), 230 (1).

Distribution. Port Phillip Bay, Victoria; 3–8 m; silty sand to sandy sediments.

Key to Australian Species of **Haliophasma**

1	Rostrum prominent, about one-fifth length of head; dactylus of pereopod 1 strongly curved, article 6 cylindrical; maxilliped article 4 terminal, about one-third length of article 3	*H. falcatum*
—	Rostrum small; dactylus of pereopod 1 curvilinear, palm blade-like, maxilliped article 4 subterminal, less than one third length of article 3	2
2	Head wider than long; rostrum broad, rounded-truncate, longer than anterolateral lobes; pereon and pleon strongly pitted or scultpured dorsally and laterally	3
—	Head as long as or longer than wide; rostrum acute to subacute, as short as or shorter than anterolateral lobes; pereon and pleon weakly or not pitted laterally and dorsally	5
3	Pereopod 1 palm strongly oblique	*H. pugnatum*
	Pereopod 1 palm on axis of limb	4
4	Pereon with 2 pairs of low carinae dorsally, separated by deep pitted grooves	*H. canale*
—	Pereon with dorsolateral grooves and few pits dorsally	*H. cribensis*
5	Exopod of uropod cleft; maxilliped article 4 extending well beyond mediodistal corner of article 3	*H. purpureum*
—	Exopod of uropod with sinuous dorsal margin, not cleft; maxilliped article 4 level with or exceeded by mediodistal corner of article 3	6
6	Telson not sculptured or ridged dorsally, a simple dome	7
—	Telson with crest, ridges or pits dorsally	8
7	Pereopod 1 with straight palm on axis of limb	*H. yarra*
—	Pereopod 1 palm strongly convex	*H. cycneum*
8	Telson with a high, narrow dorsal crest	*H. pinnatum*
—	Telson without a crest	9
9	Telson with broadly rounded end	*H. syrtis*
—	Telson with acute, upturned end	*H. elongatum*

Non-Australian Species of **Haliophasma**

H. alaticaudum Amar, 1966

H. alaticauda Amar, 1966: 193–9; figs 1, 2.

Canon de Cassidaigne, Mediterranean coast of France; 470–500 m.

H. coronicaudum Barnard, 1925

H. coronicauda Barnard, 1925a: 132.—Barnard, 1925b: 386–7.—Barnard 1940: fig. 3d.

Off Saladanha Bay, South Africa; 157 m.

H. curri Paul and Menzies, 1971
H. curri Paul and Menzies, 1971: 39–40; figs 16, 17,
Off Venezuela; 11° 03′ N, 64° 37.5′ W; 95 m.

H. dakarensis Barnard, 1925
H. dakarensis Barnard, 1925a: 133; Pl. 4, fig. 4.
Dakar, West Africa; 21–25 m.

H. foveolatum Barnard, 1940
H. foveolata Barnard, 1940: 384–5; fig. 2.—Barnard, 1955: 50–1; fig. 24.
False Bay, Port Elizabeth, South Africa; amongst corallines, worm-tubes, etc., under stones.

H. geminatum Menzies and Barnard, 1959
H. geminata Menzies and Barnard, 1959: 17–19; figs 11–12.—Menzies, 1962: 339.—Schultz, 1964: 312.—Schultz, 1966: 13.—Schultz, 1969: 103; fig. 141.
South California and northern Mexico, coastal shelves, slopes and submarine canyons, Santa Catalina Island, Santa Rosa Island, Coronada Canyon; 9–510 m.

H. hermani Barnard, 1940
H. hermani Barnard, 1940: 383–4; fig. 1.
Hermanus, South Africa; from cavity in *Allopora* coral.

H. irmae Paul and Menzies, 1971
H. irmae Paul and Menzies, 1971: 38–39; figs 14, 15.
Off Venezuela; 11° 03′ N, 64° 37.5′ W; 95 m.

H. ornatum Barnard, 1957
H. ornatum Barnard, 1957: 3; fig. 2.
Sea Point, South Africa; intertidal.

H. pseudocarinatum Barnard, 1940
H. pseudocarinata Barnard, 1940: 385–7; fig. 3.—Barnard, 1955: 5.
Port Elizabeth, False Bay, Algoa Bay, South Africa; under stones.

H. tricarinatum Barnard, 1925
H. tricarinata Barnard, 1925a: 132, Pl. 4, fig. 2.—Barnard, 1925b: 385.
Agulhas Bank, Cape St Blaize, South Africa; 73 m.

H. valeriae Paul and Menzies, 1971
H. valeriae Paul and Menzies, 1971: 37–38; figs 12, 13.
Off Venezuela; 11° 03′ N, 64° 37.5′ W; 95 m.

DISCUSSION

The diagnosis of the genus *Haliophasma* given here differs from that of Barnard (1925a) in two important aspects: (1) the maxilliped is of only 4 articles (never 5), and (2) the flagellum of antenna 1 is of 2 articles, the second minute (never multiarticulate except in adult males). The structure of the maxilliped

was the major character used by Barnard to distinguish genera in the Anthuridae and only *Haliophasma* was ambiguous in this respect. Four of Barnard's species are described as having 5-articulate maxillipeds and a multiarticulate (5–8 articles) flagellum on antenna 1 (*H. coronicaudum, H. dakarensis, H. foveolatum* and *H. pseudocarinatum*). These features and others, e.g., distinguishable pleon sutures in *H. coronicaudum,* form of the uropod endopod in *H. dakarensis* and *H. pseudocarinatum,* and the toothed pereopod 1 palm in the male *H. foveolatum,* suggest that these species should be moved to other genera. *H. hermani* also has a 5-articulate maxilliped but the antenna 1 is of the *Haliophasma* form. The description of *H. ornatum* is inadequate to place it with certainty and Barnard was undecided as to the number of maxilliped articles in *H. tricarinatum.* All of these seven species differ from the related genera *Malacanthura* Barnard, 1925, and *Apanthuroides* Menzies and Glynn, 1968, in a number of important aspects. It is not possible at this stage to place these species in other defined genera without examination of the original material.

The four American species (*Haliophasma geminatum, H. curri, H. irmae* and *H. valeriae*) are all described as lacking dorsal grooves and pits which excludes them from the genus as defined here. In addition *H. curri* posesses a 5-articulate maxilliped but is otherwise similar to *H. geminatum.* Paul and Menzies (1971) suggested that the remaining two species could be placed in a separate related genus on the basis of the teeth on the inferior margin of the dactyl of pereopod 1.

Haliophasma as diagnosed in this paper is most closely related to *Exanthura* Barnard, 1914, from which it differs mainly in the non-segmented pleon, and to *Notanthura* Monod, 1972, distinguished, among other features, by the absence of eyes.

The Australian species of *Haliophasma* can be divided into three groups as is done in the first two couplets of the key.

(1) *H. falcatum* is distinguished from all other species by the form of the rostrum, eyes, mandibular palp, maxilliped and pereopod 1.

(2) The three other species from Western Port Bay, *H. canale, H. cribensis* and *H. pugnatum,* differ from the remaining species in the shape of the head, peduncle of antenna 2, and extensive sculpture. They share the stepped transverse groove on the dorsal surface of pereonites 4–7 and modified dorsal pit, ventral keel on pereonite 1, reduced uropod exopod and medially lobed uropod peduncle.

(3) The remaining six species have in common the minute rostrum, tapering head, long antenna 2 and obsolete pitting. *H. purpureum* is separate from others in this group in having a strongly cleft uropod exopod and is also distinguished by the large article 4 of the maxilliped, approaching *H. falcatum* in this character. The species in this group differ most obviously in the form of the telson but are otherwise similar in, e.g., the shape of the maxilliped, mandibular palp and pereonal dorsal sculpture.

Only one non-Australian species of *Haliophasma* falls within the generic diagnosis used here. *H. alaticaudum* Amar is most closely allied to *H. cribensis* and related species on the basis of the shape of the head and uropods, and sculpture of the pereon, pleon and telson.

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